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Environmental Effects on Defect Growth in Composite Materials

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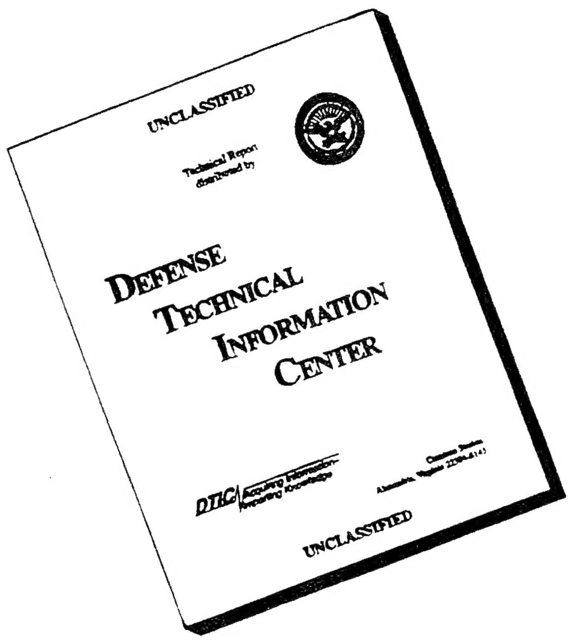

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ENVIRONMENTAL EFFECTS ON DEFECT GROWTH IN COMPOSITE MATERIALS

by
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Prepared for
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NASA Lewis Research Center
Contract NAS3-20405
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FOREWORD

This report summarizes the work accomplished on NASA Contract NAS3-20405, "Environmental Effects on Defect Growth in Composite Materials."

The program was sponsored by the National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio. Mr. G. T. Smith, NASA Lewis Research Center, was Project Manager.

Performance of this contract was under the direction of the Advanced Airplane Branch of the Boeing Military Airplane Company. Dr. R. R. June, who heads Advanced Composites Development, was the program manager. Mr. T. R. Porter was the technical leader, Pete Smith coordinated specimen fabrication, J. R. Vosper provided testing support, and L. R. Hause was responsible for ultrasonic inspection support.

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INTRODUCTION

The objective of this program was to derive data for evaluating the effects of moisture and temperature on the integrity of fiber composite components. In particular, the static and cyclic performance of three composite laminates containing flaws was investigated at room temperature and 422K (300°F) in wet and dry conditions. This program extends the results developed under Contract NAS3-19709 reported in NASA CR-135403 (ref. 1). The test results evaluate the following for each environmental condition:

a. Effect of defect type and size on static fracture

b. Influence of compression loadings on fatigue

c. Description of the effects of static and cyclic loadings on damage accumulation

d. The effect of preloading on damage growth, static strength, and cyclic load behavior

e. The comparison of wet and dry data at room and 422K (300°F) temperatures

Static fracture data were obtained for three different composite systems that had been moisture soaked to near the maximum moisture-absorption potential. The fracture test data were obtained at room temperature and immediately after the application of an abrupt temperature transient that caused the specimen to attain 422K (300°F). Three different 20-ply layups were tested. Laminate L1 represents general-purpose structure, laminate L2 is typical of polar and hoop wound pressure vessels, and laminate L3 is representative of turbine engine fan blades or tubular strut support structure. Half the test specimens were preloaded to 90% of their ultimate static load prior to moisture conditioning. Intermittent nondestructive inspection, including visual and ultrasonic techniques, were used to detect defect growth.

Cyclic test data were obtained on laminate L1 specimens in wet and dry conditions at room temperature and at 422K (300^{0}F). In these tests the specimens contained a central slit or hole. Both tension-tension (R = 0.05) and tension-compression (R = -1.0) loadings were used. The residual tensile strength was evaluated in test specimens that did not fail during cyclic loading.

SPECIMEN DESIGN AND MANUFACTURE

The test specimen materials, designs, and fabrication procedures were selected to permit the generation of data for evaluation of flawed structural components. The components considered were a general-purpose laminate structure, a polar and hoop wound pressure vessel, and a turbine engine fan blade. These materials and layups are the same as previously studied (Ref. 1).

Materials

The materials used for the program were Thornel T-300 graphite fiber, 901 S-glass fiber, and Fiberite 934 epoxy resin. Intermediate stiffness graphite/epoxy was selected as the basic material for the program because of its wide use, moderate cost, and established structural performance. The Thornel T-300 graphite fibers were selected because they can be supplied with a twist, making them suitable for general-purpose structure as well as filament winding pressure vessels. The Fiberite 934 resin system satisfied the requirements of a general-purpose epoxy and also has a wide range of applications in aerospace structures. In the turbine engine fan blade layup, 901 S-glass fiber plies were interspersed with the T-300 fiber plies to improve impact-damage resistance of the laminate. This S-glass and graphite hybrid was selected on the basis of prior work that demonstrated significantly improved impact-damage tolerance.

Layups and Stacking Sequences

Three different layups were used in the fabrication of test specimens. These layups are presented in table 1. The first layup (L1) was a 20-ply balanced layup representative of a practical aerospace application. This layup is moderately directional and would be used to support biaxial loads that approximate having about a 2:1 ratio. The second layup (L2) is representative of spacecraft pressure vessels fabricated using both polar and hoop wraps. The third layup (L3) is representative of turbine engine fan blades or, possibly, tubular support struts. The S-glass fiber was included as 0^0 plies.

The stacking sequence selected for layup L1, based on symmetry and load transfer requirements, was $((0/\pm45/0/90)_S)_2$.

The stacking sequence for layup L2 is representative of pressure vessels. There are two basic approaches to polar and hoop wrapping of aerospace pressure vessels. If the vessel wall is thin, the polar wraps can be applied before the hoop wraps. However, when the vessel wall is thick, there is slippage of the hoop wraps at the end of the cylinder. This is prevented when the polar and hoop wraps are interspersed by applying one revolution (two plies) of polar wrap followed by three plies of hoop wrap. The resulting stacking sequence is (0/0/0/+80/-80). This stacking sequence for laminate L2 was modified slightly to produce a symmetrical laminate for testing $((0/0/0/+80/-80)_2)_S$.

The stacking sequence for layup L3 is representative of those considered for use in composite turbine engine fan blades. Two possible layup approaches are the dispersed-ply approach and the core-shell approach. The dispersed-ply approach was used because such layups are less subject to delamination from foreign object impact. The representative stacking sequence then becomes $((0/+30/0^*/-30/0)_2)_S$. The asterisks indicate the plies that are replaced with S-glass to increase fracture toughness of the laminate. Replacement of the middle ply results in an even distribution of the hybridizing material throughout the panel thickness.

Test Specimen Configuration

The test specimen configuration is shown in figure 1. The 76-mm (3.0-in) width used for the majority of the tests was chosen to provide specimens large enough to preclude significant interaction between the stress concentration and stress-free specimen boundaries. The specimen was designed so that the stress concentration factor for the largest defect would be within 5% of the corresponding stress concentration factor for a plate of infinite width. The potential effect of the free edge on the fracture behavior was investigated experimentally by static testing specimens of various widths that contained the largest defects. The 0^0 laminate direction corresponds to the axial direction of the specimen. Woven fiberglass grip tabs were secondarily bonded to the specimen using a 394K (250^0F) cure adhesive.

Test Specimen Fabrication and Processing

Specimen layup and fabrication steps are illustrated in figures 2 and 3. Laminates were laid up and cured in 81-cm (32-in) wide panels having lengths up to 293 cm (120 in). The panel sizes fabricated are given in table 2. After curing fiberglass end tabs were bonded to the basic laminates and then the panels were sawed into specimen blanks. The panel fabrication steps were as follows:

a. Remove material from freezer and allow it to come to room temperature before unwrapping.

b. Unwrap material and cut tape to length. Use a template to cut angle plies to size.

c. Lay up plies.

d. Debulk after 4th, 8th, 12th, 16th, and 20th ply by holding the laminate under vacuum for 15 to 20 min.

e. Cover laminate with perforated FEP, one ply of 1581 fiberglass bleeder for each four plies of laminate, a layer of nonperforated FEP, a metal caul sheet, two layers of 1581 fiberglass breather, and a vacuum bag.

f. Cure laminate in an autoclave using the following cure cycle:

   1. Apply vacuum.

   2. Increase autoclave temperature so that laminate temperature increases at a rate of 0.5^{o} to $2.8^{o}C$ (1^{o} to $5^{o}F$) per min.

   3. Hold 60 min at $121^{o}C \pm 5.5^{o}C$ ($250^{o}F \pm 20^{o}F$).

   4. Apply 689 kPa (100 psi) pressure 15 min after the laminate reaches temperature.

5. Increase laminate temperature to $177^{\circ}C \pm 5.5^{\circ}C$ ($350^{\circ}F \pm 10^{\circ}F$) at a rate of 0.5° to $2.8^{\circ}C$ (1° to $5^{\circ}F$) per min.

6. Hold at temperature for 120 min ± 5 min, then cool under pressure.

g. Cut laminate panels to length of test specimens.

h. Lay up fiberglass-epoxy grips on the panel edges.

i. Vacuum bag and cure in an autoclave at $121^{\circ}C$ ($250^{\circ}F$).

j. Remove panels from autoclave and cut specimens from the panels.

Specimen Defect Geometry

A number of defects can occur in composite laminates due to manufacturing, handling, or inservice damage. Defects that can be found in the basic laminates are—

a. Excessive porosity or voids due to contamination of the prepreg materials, geometrical restrictions that prevent the escape of volatiles during cure, or low curing pressure

b. Wrinkled or nonaligned fibers due to improper layup, thickness changes, etc.

c. Resin-rich and resin-starved areas

d. Impact-damaged surface areas that result in delaminations or broken fibers

e. Scratched or gouged surfaces caused by mishandling during manufacture or inservice use

There are also a number of defects associated with the use of fasteners in composite structure. Some of these are—

a. Delaminations near the exit side of drilled holes due to inadequate backing or excessive drill pressure

b. Overly deep countersinks

c. Local damage due to excessive fastener torque

d. Resin-starved bearing surfaces that result from excessive drilling heat

e. New holes located where mislocated holes have been filled

The potential effects of several of these defects were assessed by testing laminates containing defects simulated by stress concentrations. These defect types can be categorized as: (1) sharp defects that break or cut filaments, (2) blunt defects that cut or break filaments, (3) delaminations, and (4) poor resin properties. The defects that include cut or broken filaments were simulated by holes and sharp slits. Both full-penetration (FP) and half-penetration (HP) holes and slits were tested (fig. 4). The delaminations were produced by subjecting the specimens to impact damage.

In addition to these stress concentrations, potential natural defects typical of the particular laminate application were also tested (fig. 5).

For laminate L1, specimens were tested that had holes containing overly deep countersinks. Deep countersinks are often unavoidable due to the lack of thickness of laminate skins. This condition was simulated by countersinking holes so that the countersink extended through the laminate thickness and left a sharp edge at the exit side of the hole.

For filament-wound pressure vessels, great care must be taken to provide the correct pressure during cure. Hence, it is appropriate to investigate the

effects of low pressure on the fracture and fatigue strength of laminate L2. Three variations of curing pressure were used: 345 kPa (50 psi), 172 kPa (25 psi), and 86 kPa (12.5 psi). The normal curing pressure is 689 kPa (100 psi).

For laminate L3, tests were conducted on a 20-ply layup that contained no S-glass. These tests were conducted to allow an evaluation of the effectiveness of the S-glass in increasing the fracture toughness of the laminates.

The hole and slit sizes selected for test were 3.18 mm (0.125 in), 9.52 mm (0.375 in), and 15.87 mm (0.625 in). These sizes, coded as 1/8, 3/8, and 5/8 respectively encompass most practical fastener diameters. They are also at the threshold of detectable damage sizes for many common inspection procedures. The same sizes were used for the surface length of the half-penetration defects, because when partial penetration damage exists in structure, the most obvious and descriptive dimension is the length of the damage on the surface.

The type and size codes used to identify each of the defects are given in table 3.

All slits were perpendicular to the primary load carrying direction of each laminate. This means that they were perpendicular to the 0^{o} fibers. The 0^{o} fibers correspond to the hoop direction of a cylindrical filament-wound pressure vessel for laminate L2.

The slits were fabricated by ultrasonic machining. Ultrasonic machining is typically used to produce cuts of difficult configuration in nonconductive materials. Circular cutter tips were machined to a thickness of 1.52 (0.06 in) and a sharp radius. The ultrasonic vibrations of the cutter produce a lapping action in an abrasive slurry that carries away the excess material as the cutter penetrates the part. The slit radius in the composite laminate was typically about 0.127 mm (0.005 in) with a smooth surface.

Figure 6 shows a typical partial penetration flaw that has been sectioned to illustrate the root geometry.

The full-penetration circular holes were drilled, and the half-penetration circular holes were end-milled.

The impact damage defect was produced by impacting the specimens with a 0.91 kg (2 lb) weight dropped from a height of 0.38m (15 in). Figure 7 is a photograph of the impact stand used. The test specimen was supported on a circular support containing a 15.9-mm (0.625-in) diameter hole. This support condition, together with the 15.9-mm (0.625-in) diameter hemispherical impactor, produced delamination damage areas approximately 15.9 mm (0.625 in) in size. Examination of sectioned specimens damaged in this manner showed delamination damage throughout the laminate thickness. Ultrasonic C-Scan records of typical impact-damaged test specimens are shown in figure 8.

WIDTH EFFECT TESTING

As shown in table 4, the static strength of laminate L1 and L3 specimens containing 5/8 FP slits and impact damage was evaluated for three specimen widths. Both static-tension and static-compression tests were performed. All tests were conducted in a room temperature air environment. The tests show a slight effect of specimen width for test specimens less than 76 mm (3.0 in) wide. The impact-damaged test specimens and the specimens with slits displayed similar compressive strengths. However, under tension loads the specimens containing slits had a much lower strength.

A 76-mm (3.0-inch) specimen width was selected as a baseline for the current testing and for previous tests (ref. 1) This selection was made from analytical studies. To confirm this selection, tests were performed on specimens containing the largest defects selected from specimens of approximately 50, 100, and 150 mm (2.0, 4.0, and 6.0 in) in width. Results of these tests, along with the 76-mm (3.0-in) specimen data was used to assess the width effect on the specimen strength and to check the validity of the specimen size selection.

In order to gain additional information, this test series was expanded to include static-compression testing of the specimens with slits as well as tension and compression tests of the specimens containing delaminations. The specimen delaminations were the result of a low-velocity impact.

The results of the width effect testing are shown in figures 9 and 10 and presented in appendix B. These data are normalized to load-per-unit width to allow a direct comparison of the various panel widths. Previous test data are also included in the figures where applicable. The trends found are similar for both the L1 and L3 laminates and similar conclusions are applicable to each.

At widths of 100 and 150 mm (4.0 and 6.0 in) there is no significant width effect shown by the data. At the 50-mm (2.0-in) width, there is a slight decrease in strength. The 76-mm (3.0 in) specimens are similar to the 100- and 150-mm (4.0- and 6.0-in) specimens. It is concluded that the selection of the 76-mm-wide test specimen size was sufficient for the largest defect size tested.

The test results permit several additional conclusions. The tension test data showed a large difference between the impact-damaged and the slit specimens. The impact-damaged specimens had tensile strengths comparable to the undamaged specimens, while the slit specimens had less than 50% of the damaged specimen strength.

The visible external damage was slight, with a 3.39J (30 in-lb) level of impact. A visual examination of the specimen after impact revealed only a slight front surface dent and no broken filaments. The dent depth was typically about 0.08 mm (0.003 in). Damage of this magnitude would probably be considered to be undetectable by visual inspection. It was concluded that impact damage that produces only delamination has little or no effect on the tensile strength for the layup patterns tested.

The compression strength of the impact-damaged specimens was approximately the same as the compression strength of the specimens containing slits with lengths equal to the delamination diameter. The magnitude of the compression fracture strength was similar to the tension fracture strength of the slit specimens. This implies that notches are equally severe in compression and tension and delaminations of the type tested are as critical as a machined notch in compression.

Examination of the failed compression panel supports a notch-sensitive fracture failure mechanism. The failure initiated at the notch edge as a local compressive failure and produced local delamination, buckling and fiber breakage which lead to a local loss of load carrying ability. In a manner analogous to tension fracture, the now-larger damage size results in even higher local stresses and unstable fractures that propagate across the specimen width.

Photographs of failed specimens shown in figures 11 and 12 illustrate this failure mode. As shown in figure 11, the specimen failure emanated from the notch and run to the specimen edge. The path of this failure is normal to the panel loading. The close-up detail of the failure shows the local buckling-shear failure of the laminate. This failed region lost the ability to support compressive loading.

The test specimens containing impact damage behaved similarly to the machined-defect specimens. The multilayer delamination supports a very small compressive load in the delaminated impact zone. In laminate L1 materials, the machined slit and impact-delaminated zone were of similar size and had a similar effect on compression fracture strengths. In laminate L3, the size of the delaminated zone was not as wide (fig. 8) as the slit length, and the test specimens had a greater compressive fracture strength. The smaller delaminated zone width is attributed to the orthotropic ply orientation $((0/+30/0/-30/0)_2)_S$ for laminate L3.

MOISTURE CONDITIONING

The specimens in this program were tested in two moisture conditions: dry and wet. The test conditions are given in tables 5 through 7. The dry condition resulted from normal storage in the laboratory from the time of cure until the test. The wet condition specimens were soaked in a water bath at 355K (180°F) for 8 weeks. These conditions represent the extremes of expected structural applications.

The length of the laboratory storage condition was typically 90 days. The laboratory temperature was continuously maintained at approximately 20°C. The laboratory relative humidity, though not controlled, was generally in the range of 40% - 50%.

The water-soak was selected to produce a condition near the maximum moisture-absorption level. The soak time and temperature were selected to minimize unrealistic effects from the conditioning treatment and to provide soak time within the scope of the program. Exposure temperatures for service conditions that can influence the rate of moisture absorption can range up to the maximum design requirements for the composite. However, it is not likely that water baths would exceed 100°C (212°F) for most composite applications and will likely be somewhat less.

In order to assess these parameters and to determine the required exposure conditions, a Boeing finite-difference computer analysis for moisture absorption was conducted on the test specimen configuration. From this study it was shown that in order to precondition the test specimens to maximum moisture content in a time that met schedule requirements, the moisture conditioning had to be performed at temperatures of 355K (180°F). This permitted completion of moisture conditioning in 8 weeks.

Weight Gain Data

During the elevated-temperature soak, test specimens were taken from the water bath at weekly intervals, towel dried, and weighed to determine the amount of

moisture gain. Previous exposure testing of similar configuration specimens has shown, that the glass tabs absorb moisture at a higher rate than the graphite/epoxy, making the actual weight-gain values hard to interpret. To offset this problem, untabbed test laminate material from each of the laminate types was soaked and weighed along with the test samples. The weight of the untabbed laminate materials was used to monitor the conditioning treatment.

To minimize variances due to conditioning procedures, the specimens were conditioned together in one tank. Program schedules required two separate batches; the first included the static test specimens (XX-2X-XX numbers), and the second included cyclic specimens (XX-3X-XX). These materials were purchased and processed at separate times under different tasks in the program thus preventing simultaneous conditioning.

The weight-gain data found for the untabbed laminates conditioned with the static test specimens is shown in figure 13. As can be seen, the final moisture level is about 1.4% to 1.5% by weight in all laminates. Laminate L3, which contains four plies of glass fiber, has the greatest final moisture content.

Test panels of laminate L2 were cured at lower than the standard 689 kPa (100 psi) autoclave pressure. The effect of cure pressure on moisture absorption is shown in figure 14. The laminate cured at the lowest pressure experienced the greatest moisture absorption. This increase in moisture level can be attributed to a higher void content in the low pressure cure laminates. The higher void content in these laminates was confirmed by ultrasonic inspection of the specimens.

Moisture conditioning of the cyclic test specimens was also monitored using untabbed laminate material. Figure 15 presents results of the weight gain for laminate L1 and L3 untabbed samples. The data points are derived from these measurements. Lines, representing the results derived from the static test specimen samples, are shown for comparison. The results are similar. The greatest difference is in the terminal weight gain response for laminate L1.

The weight gain data in the test specimens having bonded glass grip tabs are compared with the untabbed coupon data in figures 16 and 17. As expected, there is a significant influence of the end tab on the weight gain data, making the weight gain measurements in the specimens greater than expected for only the graphite/epoxy. It was assumed, however, that these results can be used to compare the tabbed specimens with each other to show trends.

Half the static test specimens were preloaded prior to moisture conditioning. These tests were used to assess the effect of potential proof testing on subsequent moisture absorption and structural properties. The preload level selected was 90% of the estimated static fracture strength. Because a range of defect types and sizes, having various fracture strengths, was evaluated, a range of preload stress levels was applied to the test specimens. The percent weight gain specimens from each of the three laminates as a function of the preload level is shown in figures 18 through 20. The three figures are for 1-, 4- and 8-week conditioning periods.

The static test specimens were evaluated in groups of four, a PL and NPL specimen for both room temperature and 422K ($300^{o}F$) tests. This gave two nonpreloaded and two preloaded test specimens for each laminate and defect geometry. For this reason the same number of nonpreloaded specimens were used to evaluate the average, maximum, and minimum lines in figures 18 through 20, as data points shown for the preloaded specimens. Also the preloaded test specimens are in pairs, one identified for subsequent room temperature testing, and one for 422K ($300^{o}F$) testing.

As can be seen from the one week soak data in figure 18, the initial weight gain in these specimens is accelerated by the preload. However, after moisture conditioning for 4 and 8 weeks, the data for laminates L1 and L2 indicate there may be a decrease in moisture absorption with preload. The data also indicate there is a greater scatter in moisture absorption of the preloaded test specimens.

A review of the data from laminate L3 indicates that one specimen from each pair of nominally identical tests absorbed moisture at a higher rate. Because these specimens were cut from adjacent sections of the same panel, were preloaded at the same time to nominally the same load, and were placed together in the water tank, this difference is as yet unexplained. A review of the crack opening displacement (COD) records for these test specimens indicates there is a trend for the specimen experiencing the greatest weight gain to show a greater damage during loading.

Interlaminar Shear Data

As a method of monitoring the effect of moisture levels on matrix properties, interlaminar shear test specimens were cut from moisture conditioned samples after 1, 2, 4 and 8 weeks of exposure. The results of these tests at room and 422K (300^{O}F) are shown in figures 21 through 25. The test specimen was 6.3 mm (0.25 in) wide and had a 4:1 span-to-thickness ratio. Five replicates were run for each test condition, with the average values and the range shown in the figures.

A trend for decreasing interlaminar shear strength with soak time was observed for all laminates. The graphite/glass L3 laminate showed the greatest effect of soak time. All laminates had a significant reduction in interlaminar shear strength at 422K (300^{O}F).

The interlaminar shear strength for the laminates cured with low autoclave pressures are compared in figure 25. The results shown are for specimens that have been conditioned for the full 8 weeks. Only the laminate materials cured at the lowest pressure of 86 kPa (12.5 psi) had reduced properties.

STATIC TESTING

Static tensile fracture strength was evaluated for the three laminates at room temperature and 422K (300°F). All testing was conducted with moisture-conditioned test specimens. Tables 5 and 6 describe conditions for each test. The four load sequences used are presented in figure 26. The first sequence (a) shows the room temperature nonpreloaded static test performed after moisture conditioning. Tests without preloading are designated NPL. The second sequence (b) shows the room temperature preload-static test sequence. Preloaded specimens are designated PL. As shown, the preloading was performed prior to moisture conditioning. The corresponding 422K (300°F) test sequences are shown in figure 26 by (c) and (d).

Test Procedures

All static tests were performed in a load controlled test machine using hydraulic specimen grips. The specimens were loaded at a rate of 1100 N/s (250 lb/s) for both preloading and fracture testing. This rate resulted in failure in about 1 min after the onset of loading. Unloading after preloading was rapid, with no hold time at the maximum load level.

The flawed test specimens were instrumented using a crack opening displacement (COD) gage across the defect. The COD gage was placed across the defect against bonded knife-edge supports; for specimens with larger holes, knife-edge supports were inserted in the hole. COD versus load was recorded for each test. These curves are included in appendix C.

Temperature Control

The 422K (300°F) elevated temperature tests were static tested after the application of an abrupt temperature transient. The test specimen was heated by a radiant heater placed near one face of the test specimen. This heating procedure produced a temperature gradient during heatup. The temperature was allowed to stabilize during static testing. This type of heating was considered to be representative of many structural applications.

The specimen heating procedures were developed using temperature survey specimens. Temperature gradients were developed across the width and along the length using front-surface, back-surface, and embedded thermocouples. Also the tests evaluated the through-the-thickness temperature gradient variation with changes in the heatup rate. The measured front- and back-surface temperatures for a 60-sec heatup rate are shown in figure 27. The temperature difference between the front and back surface was about 17K ($30^{o}F$). From these tests the through-the-thickness temperature difference during heating for a range of heatup times was determined as shown in figure 28. A heating time of 60 sec was selected for the static testing, resulting in a 17K ($30^{o}F$) temperature difference through the specimen thickness.

Test specimen loading began 180 sec after the start of heatup, allowing temperature stabilization at the time of static test. Temperature survey results indicated the through-the-thickness temperature difference was less than 3K ($5^{o}F$) at that time.

Static Test Data

The static test data are presented in tabular form in appendix A.

Static test results are shown in figures 29 through 41. The circular symbols are for the room temperature tests, and the triangular symbols are for the elevated temperature tests. Lines are shown connecting the nonpreloaded test data at room and elevated test temperatures.

Unnotched specimens showed a significant reduction in strength due to the elevated temperature for all the laminates. However, the notched strengths for laminate L1 and L3 specimens did not show this trend. The fracture strengths of notched, hot, wet laminates were greater in some cases than the room temperature values.

The elevated temperature primarily affects the matrix properties, and not the fiber strengths. Interlaminar shear strength data show this large decrease in

matrix shear strength at the elevated temperature. A reduction in matrix properties would be expected to cause a significant reduction in shear transfer around the defects at 422K (300^{O}F). Such an effect can relieve the notch stress concentration and reduce the loss of basic laminate strength.

The influence of preloading on the fracture strength after moisture conditioning is a concern when considering proof-loading techniques for composite structure. A goal of this study was to determine if the fracture strength of moisture-conditioned samples was degraded by the prior preload. The preload was applied at room temperature and prior to moisture exposure. This would be typical of a before-service proof test. The data shown in figures 29 through 41 were used to compute the ratios of the preloaded (PL) specimen to nonpreloaded (NPL) specimen fracture strengths. A similar computation was made for the dry room temperature static data from reference 1. These ratios are shown in table 8.

An examination of the static fracture data indicates that preloading does not exert a large influence on strength; most of the PL specimen data were within ± 10 % of the NPL test data. Part of the observed variations probably were due to scatter. However, there is some indication of a trend. This is shown in figure 42, where the average PL/NPL specimen strength ratio for each laminate and test condition is compared. Laminate L1 shows a 5% average increase in room temperature, dry fracture strength and a 7% average decrease in the hot, wet fracture strength, for a 12% change. The other laminates show average residual strengths that are within 4% of the initial fracture strengths for all environments.

The fact that, the PL/NPL ratio was greater than 1.0 for laminate L2 and less than 1.0 for laminate L3 may be significant, but the magnitude of the change in strength is very small and probably not critical to proof-loading applications.

The autoclave pressure during cure had only a small effect on the fracture strength of laminate L2, as shown in figure 37. This is in contrast to the interlaminar shear strength reduction presented in figure 25. This is consistent with the fracture strength primary controlled by fiber properties and the interlaminar strength primary controlled by matrix properties.

Figures 43 through 52 compare wet and dry test data. The wet room temperature tests typically exceed the dry room temperature strengths by 10% in the all-graphite L1 and L2 laminates. The graphite-glass L3 hybrid laminate displayed the reverse trend, with the dry laminate having the greater strength.

The influence of moisture conditioning on fracture strength was determined by comparing the dry room temperature tests reported in a previous program (ref. 1) with present data. These tests had identical layups, materials, and specimen configurations but a different material order. A comparison of these materials showed a 67% difference in fiber volumes for the present tests and 62% for the previous tests. This difference is also reflected by material thickness. Because the quantity of graphite fiber is controlled by Boeing specification and remains constant, the data were compared on a basis of total load rather than stress.

Static Fracture Analysis

There have been a number of techniques proposed for the analysis of composite fracture. In these linear stress analysis methods the defect size is shown to control laminate strength. The current test data is analyzed using the inherent flaw analysis (ref. 2). In this analysis the typical fracture relations for slits and holes are modified by adding an inherent dimension a_o; that is,

$$K_c = \sigma_c \left(\pi (a + a_o)\right)^{\frac{1}{2}} \quad \text{for slits}$$

$$K_c = \sigma_c \left(\pi a_o\right)^{\frac{1}{2}} F\left(\frac{a_o}{R}\right) \quad \text{for holes}$$

$$K_c = \sigma_c \left(\pi a_o\right)^{\frac{1}{2}} \quad \text{for unnotched strength}$$

where F() is the standard Bowie function for cracks from a hole, and K_c, σ_c, a, and R are fracture toughness, fracture stress, half slit length, and hole radius, respectively.

Figures 53 through 55 compare the static test data for the FP slit specimens and the least square fit fracture lines. The figures also include the values of the fracture toughness and inherent flaw size that were computed.

Damage Growth

The damage growth was monitored by the crack opening displacement instrumentation, periodic C-scan, and visual observation. These results for all the static testing are presented in appendix C.

Figure 56 shows typical C-scan damage experienced by the three laminate materials during static loading. As shown, there is a difference in the size of delamination damage experienced by the three laminates. Laminate L1 shows the lowest tendency to delaminate at the notch, while L2 shows extensive damage growth. This damage growth difference results from clustering of the plies and the low inplane shear strength in laminate L2 ($0_3 \pm 80$). Laminates L1 ($0/\pm 45/0/90$) and L3 ($0/+30/0/-30/0$) have dispersed ply orientations and higher inplane shear because of the fiber orientation.

The half-penetration defect test specimens show a damage indication above and below the notch after load. This damage indication is produced by a delamination at the specimen midplane due to the interlaminar shear. The through-penetration slit specimens show damage growth at the notch tips. This growth is again due to the shear stresses, but in this case it is inplane shear. Visual examination reveals splits near the notch tips for both defect types.

The crack opening displacement records for the three laminates and two defects types are compared in figure 57. These two types of damage growth behavior were typical of all machined defects tested.

Ultrasonic examinations of the preloaded unflawed test samples are shown in Figure 58. The scans for laminates L1 and L3 before and after preload did not show any change. The laminate L2 scan showed extensive internal damage. Careful examination of the scan indicates that the damage is in the (± 80) plies. An

examination of polished edges on these specimens indicates there is microcracking in the ($\pm$80) plies at the applied strain levels for this specimen configuration. C-scan records after moisture conditioning (fig. 59) indicates some fill-in of this damage by moisture. This then can be used to explain the accelerated moisture absorption shown in figure 18 for this specimen.

The C-scan records for specimens with cure cycles having low autoclave pressure are shown in figures 60 through 62. These records show a significant reduction in laminate quality at the lowest pressure and some reduction at the next to lowest. This indication of poor quality is probably due to voids or poor interlaminar bonding. It is interesting to note that moisture conditioning reduces the attenuation shown in the low-pressure cure laminates, indicating a fill-in of the poor interlaminar bond or voids.

CYCLIC TESTING

The test matrix for the environmental cyclic tests is shown in table 7. The approach used is a parametric variation of environmental and testing parameters to evaluate their effect. The cyclic testing was limited to one laminate $((0/\pm45/0/90)_S)_2$ and two defects (5/8 FP hole and 5/8 FP slit). The target life (cycles) defines the maximum applied number of load cycles before the cyclic loading was stopped and the specimen tested for residual strength.

Test Procedures

All cyclic and static loading was conducted in a laboratory air environment. The wet tests were room air cyclic tests of specimens that had been moisture preconditioned in a water bath for 8 weeks. This was the same preconditioning used for the static wet specimens. The moisture content in the graphite/epoxy laminate after this exposure was approximately 1.5%. The preconditioned specimens were stored between tests in a wet environment at room temperature to maintain their moisture level.

Both tension-tension (R = 0.05) and tension-compression (R = -1) cyclic loading patterns were applied as shown in Figure 63. In the event that the target cyclic life was reached without a fatigue failure, the specimen was given an ultrasonic inspection and then static loaded to failure to establish residual strength. The effect of a preload cycle was determined from the preload tests.

Test loads were selected by evaluating previous results (ref. 1) for dry room temperature conditions. The number of load levels was minimized to allow a direct comparison of the life results from various test conditions. All tension-tension tests (R = 0.05) were at 46.7 KN (10.5 kip). This load was the upper bound used for cyclic testing in order to prevent single cycle failures and is about 85% of the average dry room temperature static strength. Because of the similar response of the 5/8 FP hole and slit, the same loads were used for both defect types.

As noted, selected specimens were preloaded. As in the static tests, the preload was applied to the test specimens prior to moisture conditioning. This preload is a one-time load application with no hold time at maximum load. The level was 48.9 KN (11.0 kip) for both defect types, which was approximately 90% of the anticipated room temperature dry fracture strength.

Cyclic testing was performed in servohydraulic test machines at a maximum frequency of 5 Hz. Figure 64 is a photograph of the test setup. The cyclic frequency was reduced for the first few cycles and while reading the instrumentation.

Load was transmitted to the specimen through bolted friction grips. The compressive-loaded specimens were restrained from buckling through the use of two faceplates, one against each specimen surface. The faceplates had a 50.8 mm (2 in) diameter hole centered over the defect to allow local out-of-plane deformation and to allow inspection of the specimen damage. The inspection hole diameter was smaller than specimen width, allowing full length support at the specimen edge.

All the test specimens had crack opening displacement (COD) instrumentation to monitor changes during cyclic load. The COD gage output was recorded periodically during the cyclic test life. This information was used to monitor damage growth in the test specimens due to loading and environmental conditions.

Inspection Procedures

Ultrasonic inspection of the test specimens was conducted before the specimens were installed in the test machine. The preloaded specimens were reinspected following the preload cycle. In addition to these pretest inspections, fatigue specimens were reinspected during the cyclic life of the specimen. For specimens that reached the targeted cyclic life without failure, an inspection was performed before the residual strength measurements were conducted. These ultrasonic scan records are included in appendix D.

To identify potential damage from the unloading portion of the preload cycle, pulse-echo ultrasonic inspection was conducted before preload, while at load, and after unloading. This was performed in the test machine using a hand-held transducer. It was found from these studies that there was only limited damage growth during preloading. This is consistent with the ultrasonic scan results and for results for 5/8 slits and holes in laminate L1. A comparison of the pulse echo inspection data taken during maximum load and after unloading indicated that this damage occurred on loading, with no detectable damage resulting from unloading.

The ultrasonic inspection during the cyclic test life was made by removing the specimen from test. The specimen removal procedure was adapted to allow better techniques to be used during inspection. The inspection times selected were after 10 cycles for the 10^3 cyclic life specimens and after 100 cycles for the 10^6 and 10^7 cyclic life specimens. These lives were selected to supplement the available data at 1, 10^3, 10^5, and 10^6 cycles.

Temperature Control

The tension-tension test specimens, were heated with a radiant heater on one face. This procedure is similar to that previously used for static testing. The temperature gradient through the thickness was found to be less than five 3 K (5^{o}F) after about 2 min. at temperature. Heating from one side allowed easy specimen inspection and access for the COD gage.

The tension-compression testing required specimen stabilization plates that interfered with temperature control and heating. This problem was overcome by placing resistance heaters on the stabilizing plates in addition to the radiant heater. In this manner the specimen temperature is controlled to within five 3 K (5^{o}F) of 422K (300^{o}F). These procedures allowed access to the specimen for inspection and COD instrumentation. Access to the specimen face was through the 50.8 mm (2 in) diameter central holes in the stabilization plates.

Test Results

Dry room temperature test results are presented in figures 65 through 68. The results are shown as maximum cyclic load versus applied load cycles. Specimens that did not fail during the cyclic test (circles with arrows) were residual static tested to failure. The residual static test results are shown as triangular points in the figures. Results from similar tests (ref. 1) are also included in the figures and identified with the number (1). The test data support the combinations of the results from these programs.

The results for the slits and the holes were similar for both the tension-tension and the tension-compression tests. Under tension-tension loading there was a high endurance limit, and the residual static strength increased with the application of cyclic loads. Under tension-compression loading the endurance load was about 60% of the static tension load for the long cyclic lives. The residual static tension strength data indicates an increase as found for tension-tension loading, although the limited data prevents firm conclusions.

Cyclic test results for room temperature wet tests are presented in figures 69 through 72. These data show a trend similar to the dry testing.

In both of these sets of data there does not seem to be an effect from the preloading on the cyclic lives.

The wet room temperature results are compared with the dry room temperature test data in figures 73 through 76. Figures 73 and 74 compare the residual strength data from the tension-tension tests, and figures 75 and 76 compare the cyclic life data from the tension-compression tests. The open symbols are for the dry tests, and the closed symbols are for the preconditioned (wet) specimens. The preloaded and nonpreloaded specimens are not differentiated in this presentation.

For both the hole and slit defects the residual strength of the wet test specimens generally exceeds the identical dry test specimens. There is an indication that the residual strength of the wet and dry specimens are the same after 10 million cycles.

The comparison of the cyclic test data for the tension-compression testing indicated a significant reduction (greater than an order of magnitude in life) for the wet specimen test data. This reduction is probably the result of reduced compressive properties and increased delamination in the wet specimens due to the reduced matrix strength.

Figures 77 through 80 present the dry 422K (300^{o}F) test results. The presentation format is the same as for the other test conditions. The test loadings were maintained at the same levels as used for the previous series. As shown, the tension-tension tests again generally survived to the planned life, whereas the tension-compression specimens experienced fatigue failure.

These data are compared to the room temperature tests in figures 81 through 84. The elevated temperature tests are similar to the room temperature wet tests; i.e., higher residual strength and significantly shorter fatigue lives. However, it should be noted that residual strength tests were conducted at room temperature for both the room and 422K (300^{o}F) cyclic tests. The difference in residual strength is due to the prior effect of temperature on damage growth during load cycling, while the early fatigue failures at 422K (300^{o}F) for the tension-compression tests are due to the temperature effects on both strength and damage growth.

Figures 85 through 88 present the wet 422K (300^{o}F) test results. The tension-tension test loadings were maintained the same as for the previous testing. However, for the tension-compresson testing the cyclic load had to be reduced to prevent static compressive load failures.

These data are compared to the 422K (300^{o}F) wet specimens in figures 89 through 92. It is interesting to note that the curve for the residual strength of the wet test specimens intersects the curve for the dry specimen residual strength at the long lives. One explanation could be drying of the test samples during cycling loading. This would be reasonable because of the potential acceleration in the diffusion rates from the cyclic loading. Also this would be expected in the 422K (300^{o}F) tests where the diffusion rates would be high due to the temperature.

CONCLUSIONS

Three composite 20-ply laminates representative of general structure, pressure vessels, and turbine engine fan blades were studied to develop data on the moisture and temperature effects on defect tolerance. The test results presented apply to the specific laminates and test conditions evaluated. However, the trends define general behavior for a wide range of composite materials and help to define expected structural behavior. Some of the conclusions that were made from the test data, and which are discussed in more detail in the report, are as follows:

a. Defects in the composite laminates that cut filaments significantly reduced the strength.

b. The failure in the test specimens with cut filaments initiated at the stress concentration and propagated across the specimen width. The failure mode and failure stress were similar for both tension and compression loading.

c. The fracture strength was a direct function of defect size. Only when specimen width was less than about four times the defect size were the edge effects significant.

d. When specimens had impact damage delaminations with no broken filaments there was no reduction in tension strength but there was a reduction in compression strength. The compression strength was reduced to the same value as for a machined defect of the same size as the delamination size.

e. There was little difference between the performance of laminates with circular holes or sharp slits in the sizes tested.

f. Half-penetration defects were less severe than full-penetration defects of the same surface length.

g. Absorbed moisture had a small effect on the static fracture strength at room temperature. In graphite laminates the wet specimens had a greater strength, whereas the hybrid laminates had a reduced strength when wet.

h. Preloading had a small effect on moisture absorption and residual static strength. The preload accelerated initial moisture gain but not the end result. In laminate L1 the preloading increased the dry room temperature residual strength and reduced the elevated temperature wet value. The other conditions and laminates showed little change.

i. Graphite fiber composite materials were relatively insensitive to tension-tension fatigue, even when at 422K ($300^{O}F$) and wet. However, the application of compression loadings (R = -1.0) yielded fatigue failures at significantly lower loads than in tension.

j. Moisture and temperature, independently and in combination, had a significant effect on tension-compression fatigue behavior.

Table 1. Structural Laminates Evaluated

Designation	Material	Layup	Application
L1	Thornel 300/fiberite 934 (T300/934)	$\left[(0/\pm45/0/90)\right]_2$	General structure
L2	T300/934	$\left[(0_3/\pm80)_2\right]_S$	Pressure vessels
L3	T300/934 with 901-S	$\left[(0/+30/0^*/-30/0)_2\right]_S$	Turbine engine fan blades or support struts

*Plies that are replaced with S-glass

Table 2. Summary of Test Laminate Construction

Specimen number	Test type	Laminate number	Stacking sequence	Panel size m (inXin)
L1-21-XX	Static	L1	$\left[(0/\pm45/0/90)_S\right]_2$	0.81 X 3.05 (32X120)
L2-2X-XX	Static	L2	$\left[(0_3/\pm80)_2\right]_S$	0.81 X 2.92 (32X115) [1]
L3-21-XX	Static	L3	[2] $\left[(0/+30/0^*/-30/0)_2\right]_S$	0.81 X 1.90 (32X75)
L3-22-XX	Static	L3 all graphite	$\left[(0/+30/0)-30/0)_2\right]_S$	0.81 X .76 (32X30)
L1-31-XX	Cyclic	L1	$\left[(0/\pm45/0/90)_S\right]_2$	0.81 X 1.52 (32X60) [3]

[1] Test panel was cut after layup into one 0.81 X 1.96 (32X77) panel and three smaller panels prior to cure for the low pressure cure cycles

[2] * denotes S-glass ply

[3] Two panels were required

Table 3. Defect Type and Size Code

Defect type \ Approximate diameter or surface length mm (in)	3.18 (0.125)	9.52 (0.375)	15.9 (0.625)
Full-penetration hole	1/8 FP HOLE	3/8 FP HOLE	5/8 FP HOLE
Half-penetration hole [1]	1/8 HP HOLE	3/8 HP HOLE	5/8 HP HOLE
Full-penetration slit	1/8 FP SLIT	3/8 FP SLIT	5/8 FP SLIT
Half-penetration slit [1]	1/8 HP SLIT	3/8 HP SLIT	5/8 HP SLIT
100-degree full-depth countersink hole	1/8 CSK HOLE	3/8 CSK HOLE	5/8 CSK HOLE
Circular disbond defect between 15th and 16th plies	–	–	5/8 DISBOND
Low velocity impact damage 3.38 N-m (30 in-lb')	–	–	IMPACT

[1] HP defects are 1.5 mm (0.060 in) deep

Table 4. Width Effect Test Matrix

Specimen configuration		L1						L3					
	Laminate	L_1						L_3					
	Defect code	5/8 FP SLIT			IMPACT			5/8 FP SLIT			IMPACT		
	Specimen mm width (in)	50 (2)	100 (4)	150 (6)	50 (2)	100 (4)	150 (6)	50 (2)	100 (4)	150 (6)	(50 (2)	100 (4)	150 (6)
Loading condition	Static tension	1	1	1	1	1	1	1	1	1	1	1	1
	static compression	1	1	1	1	1	1	1	1	1	1	1	1

Table 5. Static Fracture Test Matrix of Wet Room Temperature Specimens

Layup pattern and loading condition		Defect type and degree of penetration															
		S_o	Circular holes						Sharp slits						Natural		
			1/8		3/8		5/8		1/8		3/8		5/8		S_1	S_2	S_3
		–	FP	HP	FP	HP	FP	HP	FP	HP	FP	HP	FP	HP	–	–	–
L_1	NPL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	PL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
L_2	NPL	1	1	–	1	–	1	–	1	1	1	1	1	1	1	1	1
	PL	1	1	–	1	–	1	–	1	1	1	1	1	1	1	1	1
L_3	NPL	1	1	–	1	–	1	–	1	1	1	1	1	1	1	1	1
	PL	1	1	–	1	–	1	–	1	1	1	1	1	1	1	1	1

Static tests at room temperature after moisture conditioning

L_1 – Laminate L_1 $((0/\pm45/0/90)_S)_2$

L_2 – Laminate L_2 $((0_3/\pm80)_2)_S$

L_3 – Laminate L_3 $((0/+30/0^*/-30/0)_2)_S$

NPL – No preload

PL – Preload to 90 percent estimated strength prior to moisture conditioning

FP – Full penetration

HP – Half penetration

S_o – Unflawed test specimen

S_1, S_2, S_3 – Natural defects (see Figure 5)

Table 6. Static Fracture Test Matrix of Wet Thermal Spike Specimens

Layup pattern and loading condition		Defect type and degree of penetration															
		S_o	Circular holes						Sharp slits						Natural		
			1/8		3/8		5/8		1/8		3/8		5/8		S_1	S_2	S_3
		–	FP	HP	FP	HP	FP	HP	FP	HP	FP	HP	FP	HP	–	–	–
L_1	NPL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	PL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
L_2	NPL	1	1	–	1	–	1	–	1	1	1	1	1	1	1	1	1
	PL	1	1	–	1	–	1	–	1	1	1	1	1	1	1	1	1
L_3	NPL	1	1	–	1	–	1	–	1	1	1	1	1	1	1	1	1
	PL	1	1	–	1	–	1	–	1	1	1	1	1	1	1	1	1

Static tests at 422K (300°F) after abrupt heating from room temperature all specimens moisture conditioned

L_1 – Laminate L_1 $((0/\pm45/0/90)_S)_2$

L_2 – Laminate L_2 $((0_3/\pm80)_2)_S$

L_3 – Laminate L_3 $((0/+30/0^*/-30/0)_2)_S$

NPL – No preload

PL – Preload to 90 percent estimated strength prior to moisture conditioning

FP – Full penetration

HP – Half penetration

S_o – Unflawed test specimen

S_1, S_2, S_3 – Natural defects (see Figure 5)

Table 7. Environmental Cyclic Test Matrix

Laminate	Defect code	Load ratio, R (P_{min}/P_{max})	Preload, % σ ult	Number of tests at designated test condition										
				Test conditions										
				Room temperature – dry		Room temperature wet			422K (300°F) dry			422K (300°F) wet		
				Target life (cycles)		Target life (cycles)			Target life (cycles)			Target life (cycles)		
				10^6	10^7	10^3	10^6	10^7	10^3	10^6	10^7	10^3	10^6	10^7
L_1	5/8 FP HOLE	0.05	0	1	1	1	1	1	1	1	1	1	1	1
			90		1	1	1		1	1		1	1	
		-1.0	0	1	1	1	1	1	1	1	1	1	1	1
			90		1	1	1		1	1		1	1	
	5/8 FP SLIT	0.05	0	1	1	1	1	1	1	1	1	1	1	1
			90		1	1	1		1	1		1	1	
		-1.0	0	1	1	1	1	1	1	1	1	1	1	1
			90		1	1	1		1	1		1	1	

Table 8. Influence of Preload on Static Strength

Defect code		Ratio of Preload (PL) to Non Preload (NPL) static strength											
		Laminate L_1			Laminate L_2			Laminate L_3 hybrid			Laminate L_3 all graphite		
		Room		422K	Room		422K	Room		422K	Room		422K
		Dry	Wet	Wet	Dry	Wet	Wet	Dry	Wet	Wet	Dry	Wet	Wet
FP SLIT	1/8	1.11	1.02	0.92	1.01	1.24	1.02	0.99	1.06	0.89	0.94		
	3/8	1.01	1.08	0.89	0.97	1.05	0.99	1.00	0.98	0.81			
	5/8	1.04	1.08	0.89	0.92	0.94	1.08	0.97	0.98	0.98	0.91	0.92	0.89
FP HOLE	1/8	1.10	1.00	0.96	1.00	1.04	1.05	0.98	1.00	1.03			
	3/8	1.12	0.99	0.79	1.09	0.93	1.01	1.04	1.01	0.81			
	5/8	1.08	1.06	0.83	1.19	0.90	1.07	–	0.92	1.00		0.97	0.91
HP SLIT	1/8	1.12	1.00	0.82	1.19	1.03	0.99	0.95	0.97	0.93			
	3/8	1.17	0.90	0.97	0.92	0.93	1.00	0.93	1.12	0.93			
	5/8	1.05	1.19	0.90	–	0.99	1.07	–	0.75	1.23	1.05	1.11	0.88
HP HOLE	1/8	0.95	0.92	0.87									
	3/8	–	0.90	0.93									
	5/8	0.96	0.92	1.07									
CSK HOLE	1/8	1.03	0.90	1.02									
	3/8	–	1.11	1.05									
	5/8	1.09	1.00	0.87									
NONE		–	0.99	0.91	0.99	0.98	1.04	0.95	0.96	0.95			

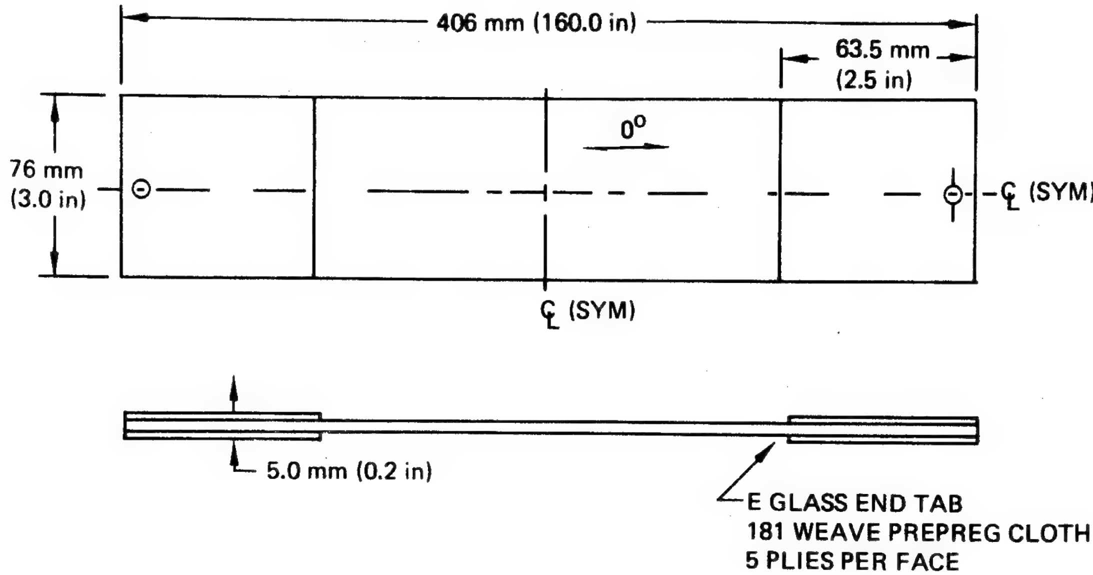


Figure 1. Test Specimen Configuration

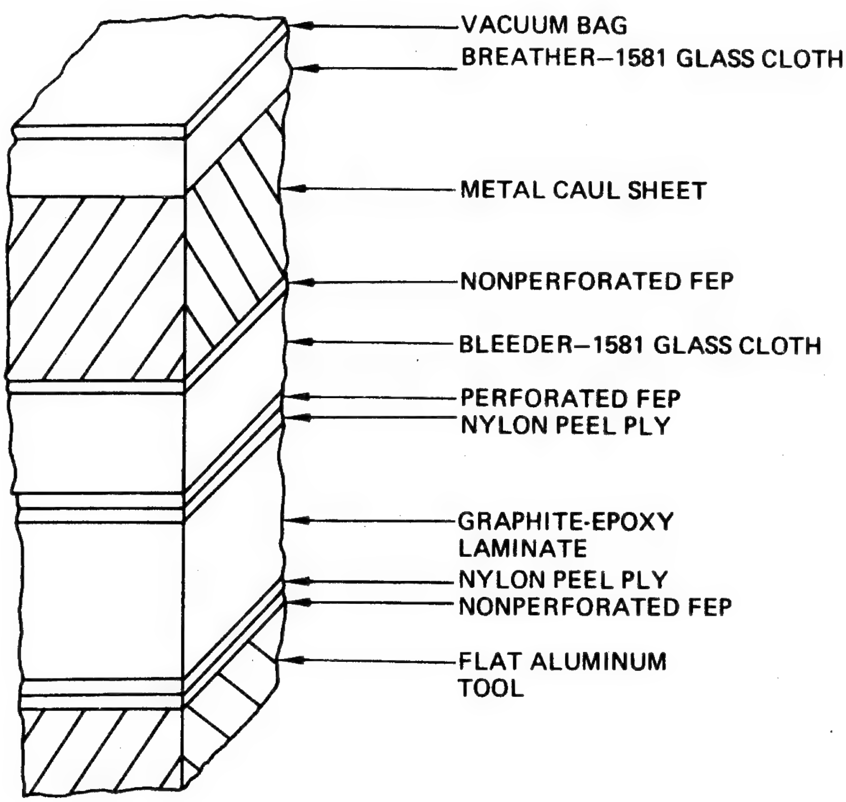


Figure 2. Specimen Laminate Layup Sequence

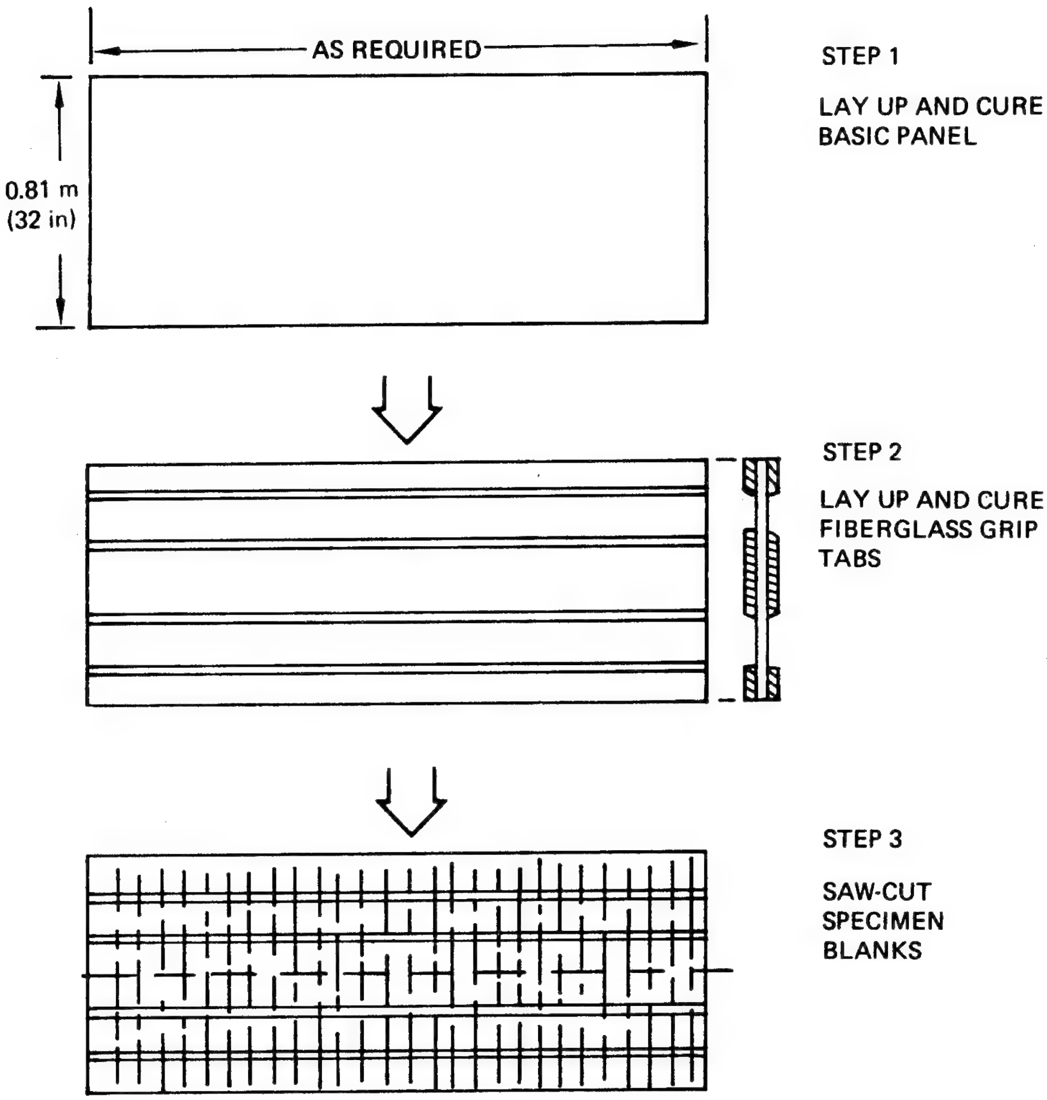


Figure 3. Specimen Cutting Procedure

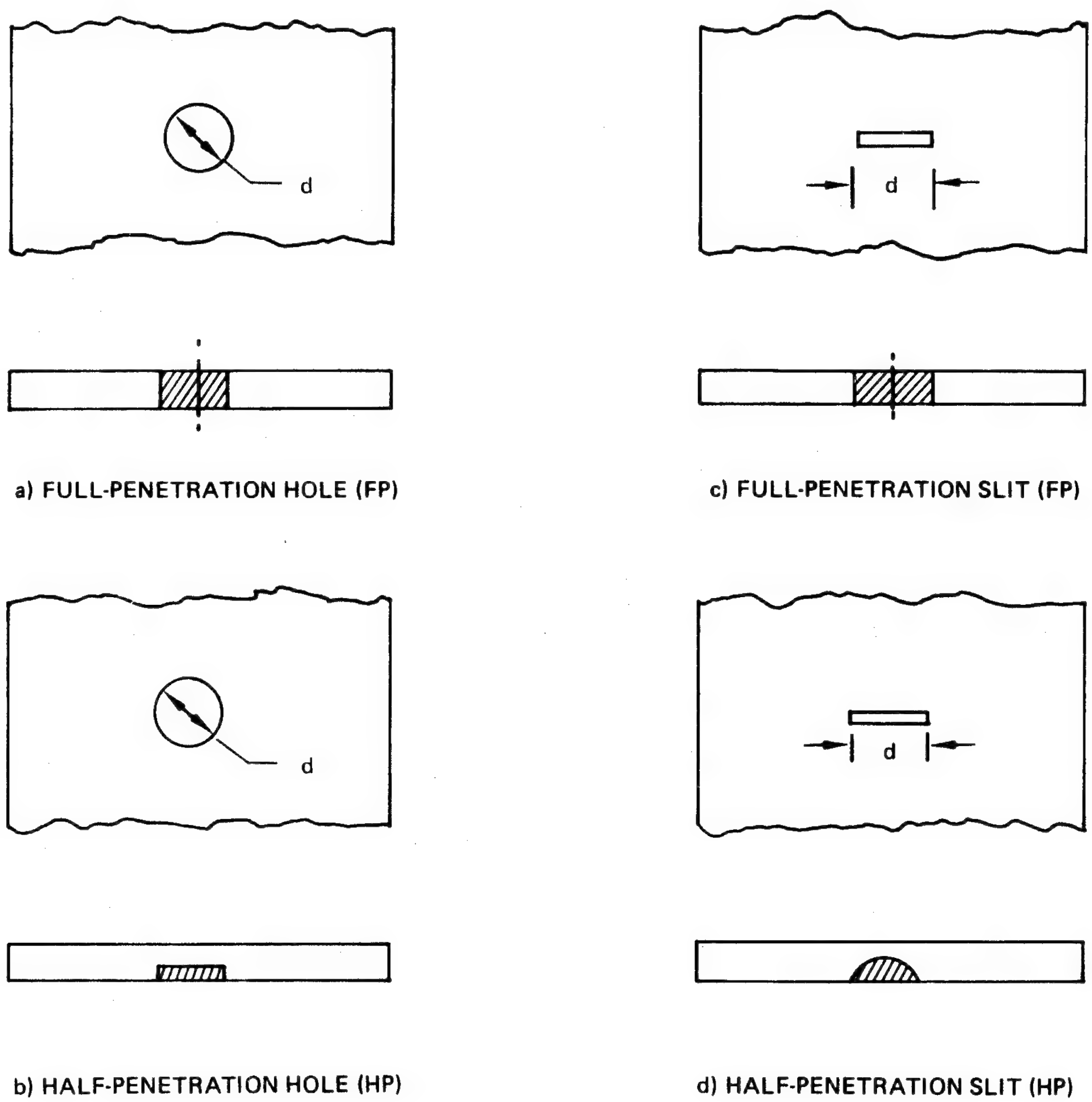


Figure 4. Stress Concentration Configurations

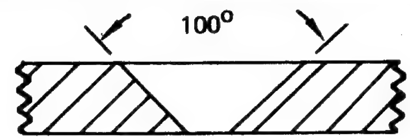
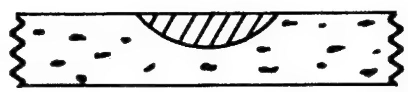
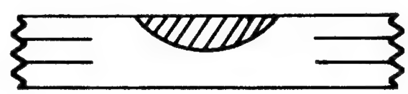
LAMINATE	DEFECT
L_1	 DEEP COUNTERSINK
L_2	 VOIDS
L_3	 NO HYBRID FIBERS

Figure 5. Natural Defects

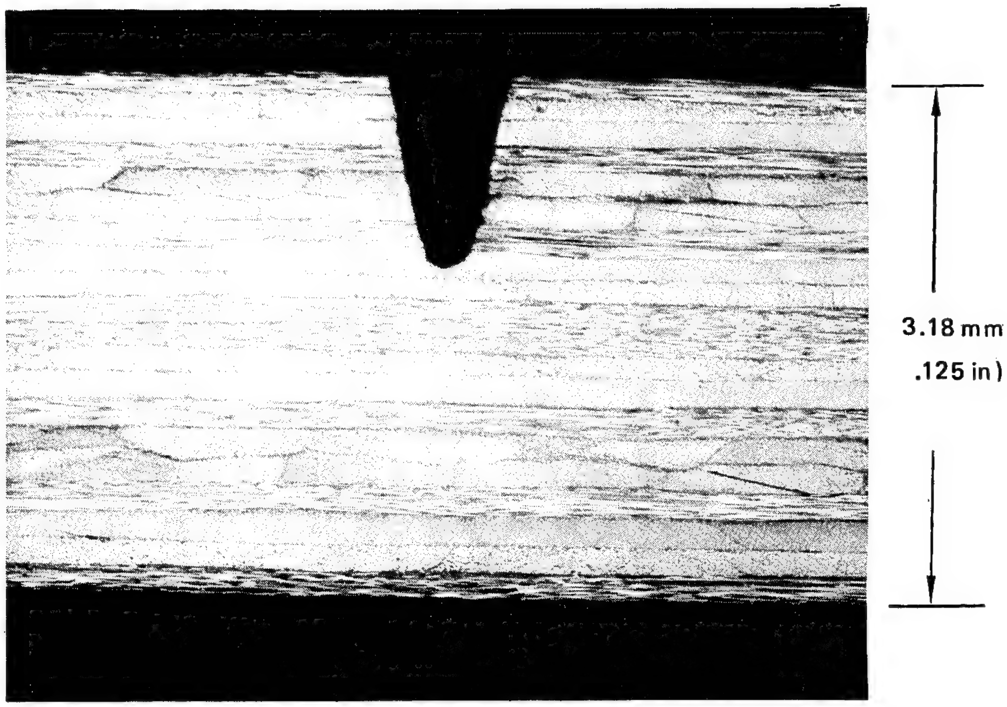


Figure 6. Photomicrograph Showing Root of Ultrasonically Machined Flaw

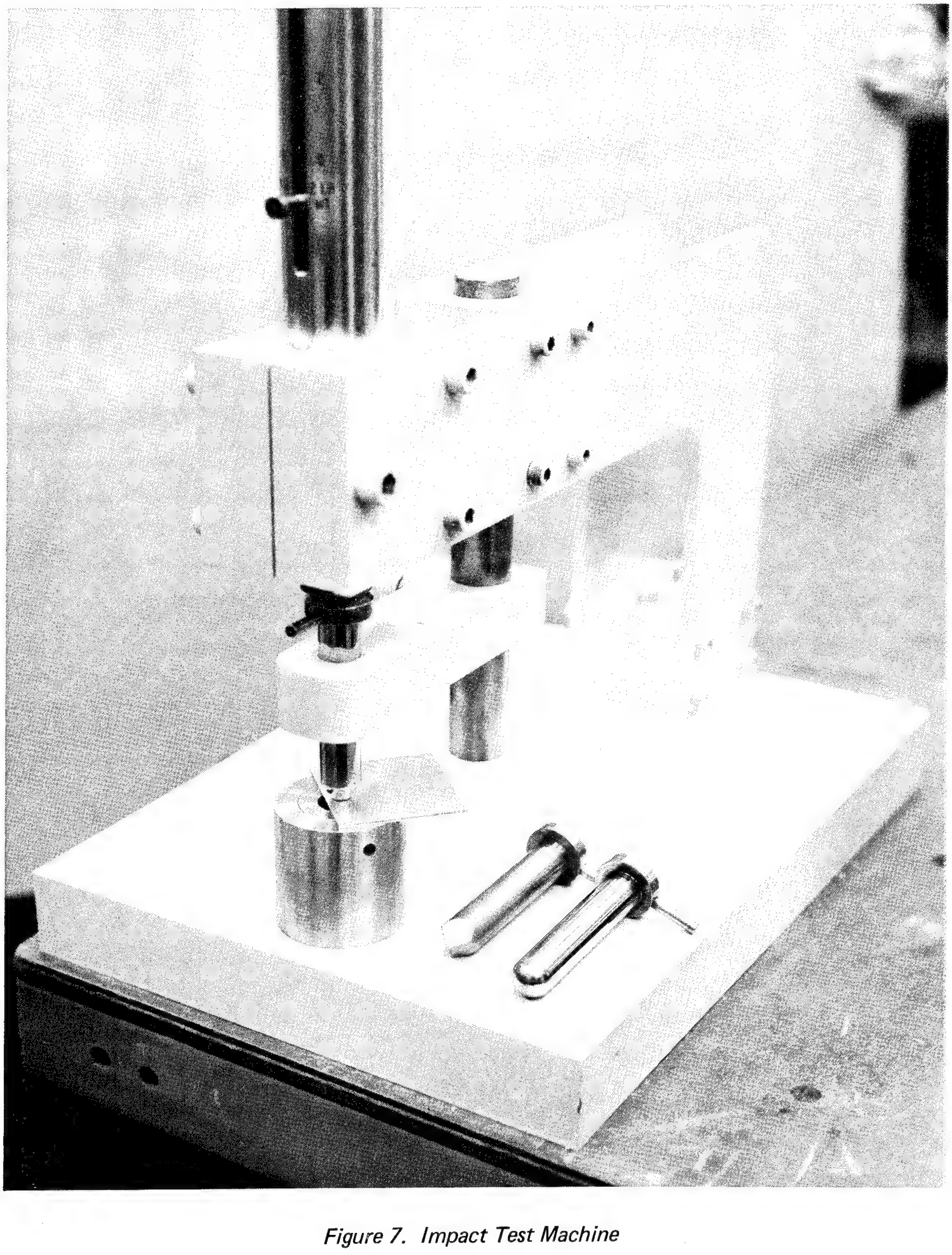


Figure 7. Impact Test Machine

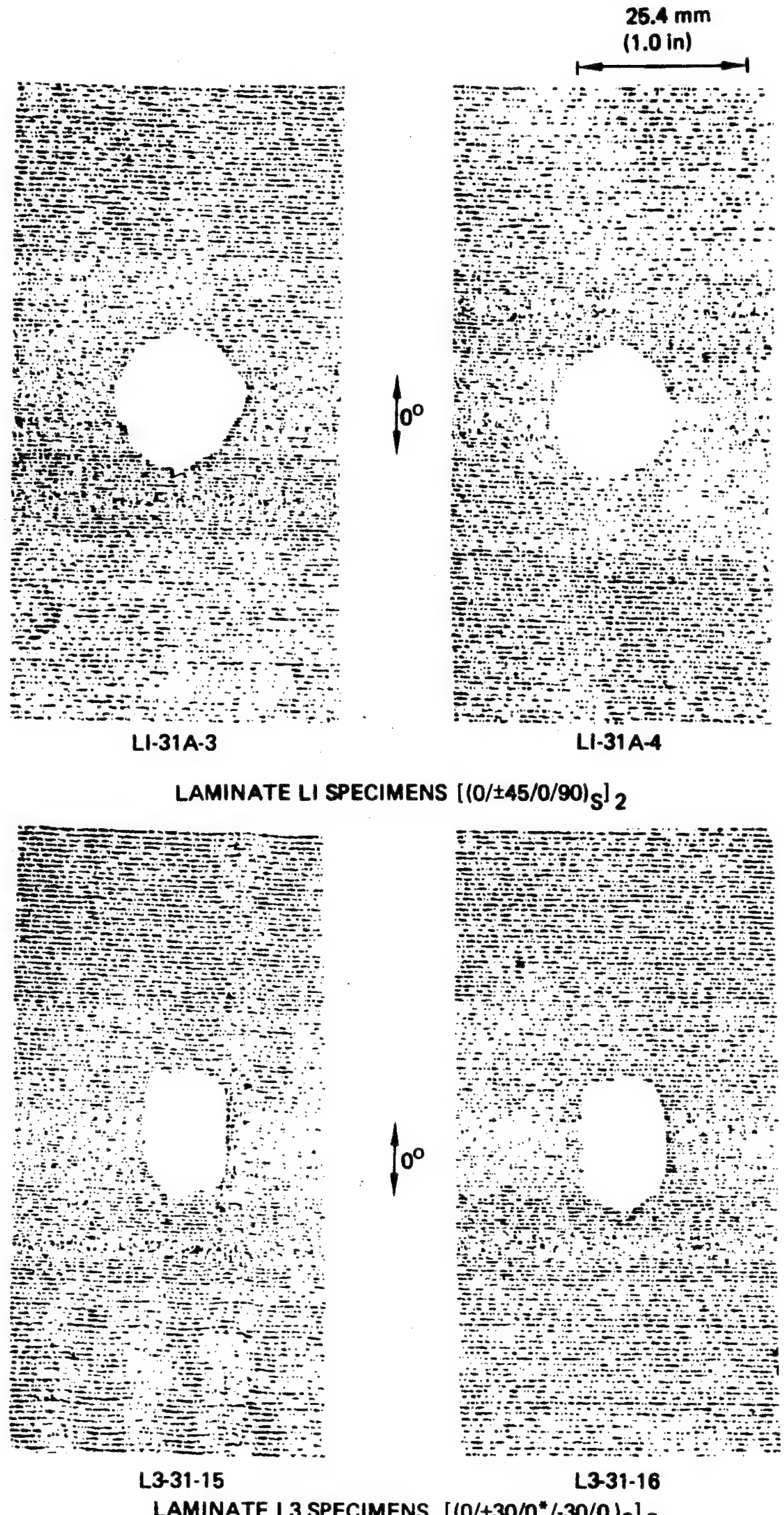


Figure 8. Ultrasonic Scan Records for Impact Damage

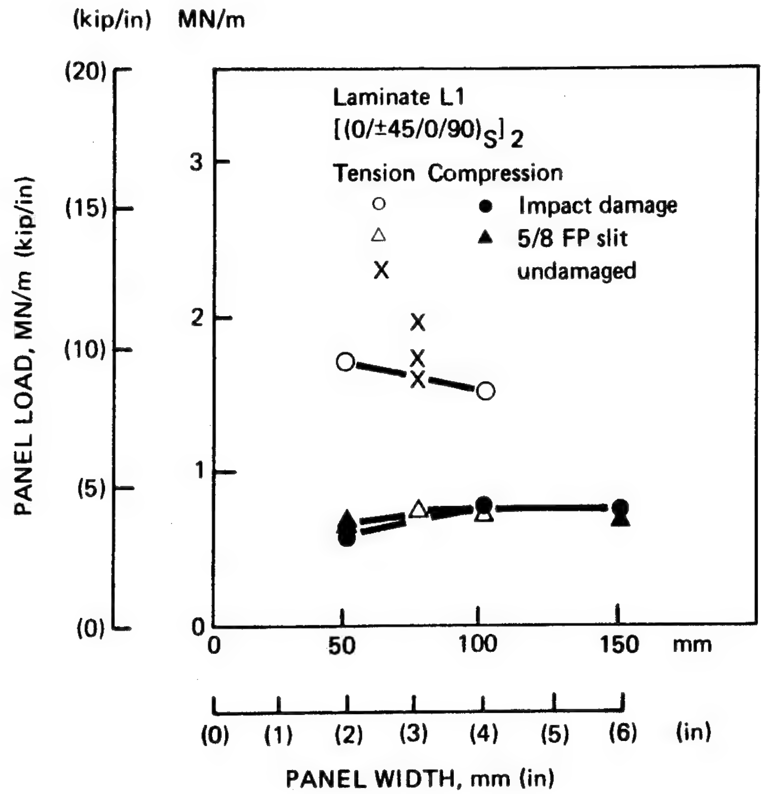


Figure 9. Effect of Width on Static Strength of Laminate L1

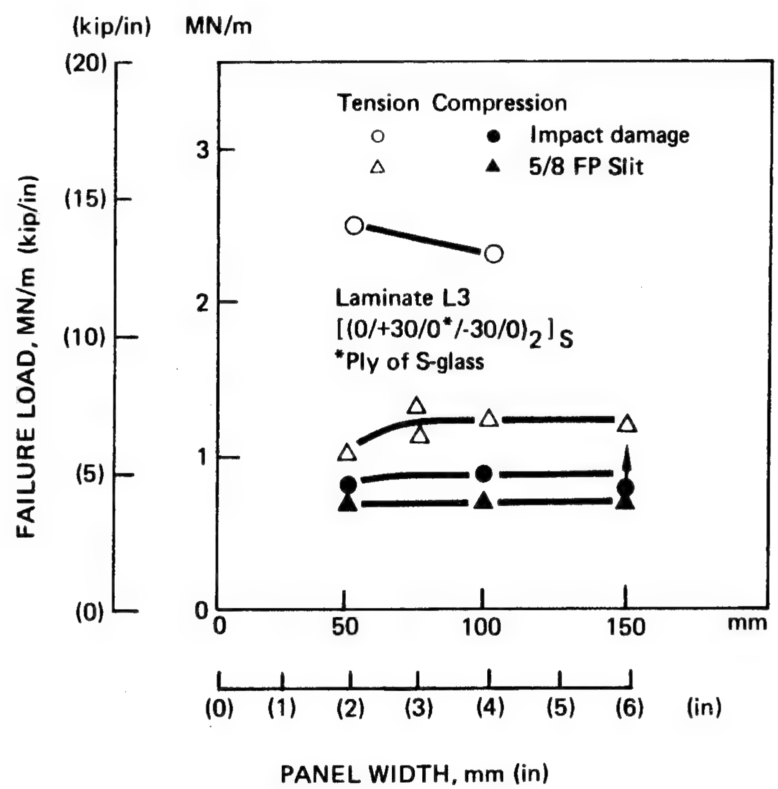


Figure 10. Effect of Width on Static Strength of Laminate L3

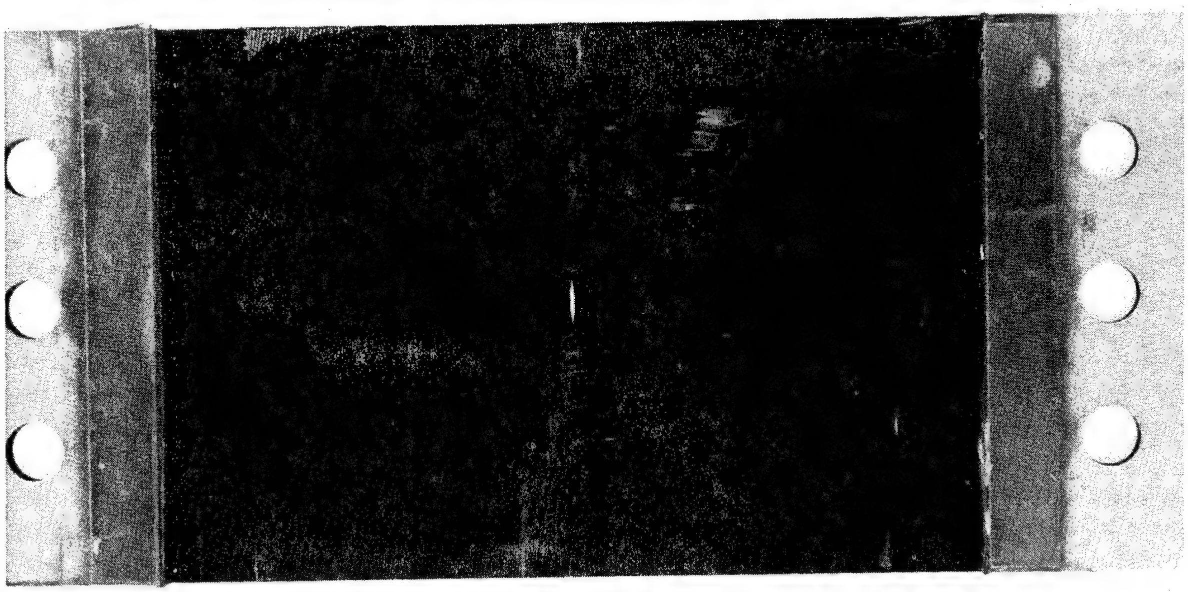


Figure 11. Photograph of Compression Fracture Specimen

Figure 12. Edge Detail of Compression Fracture

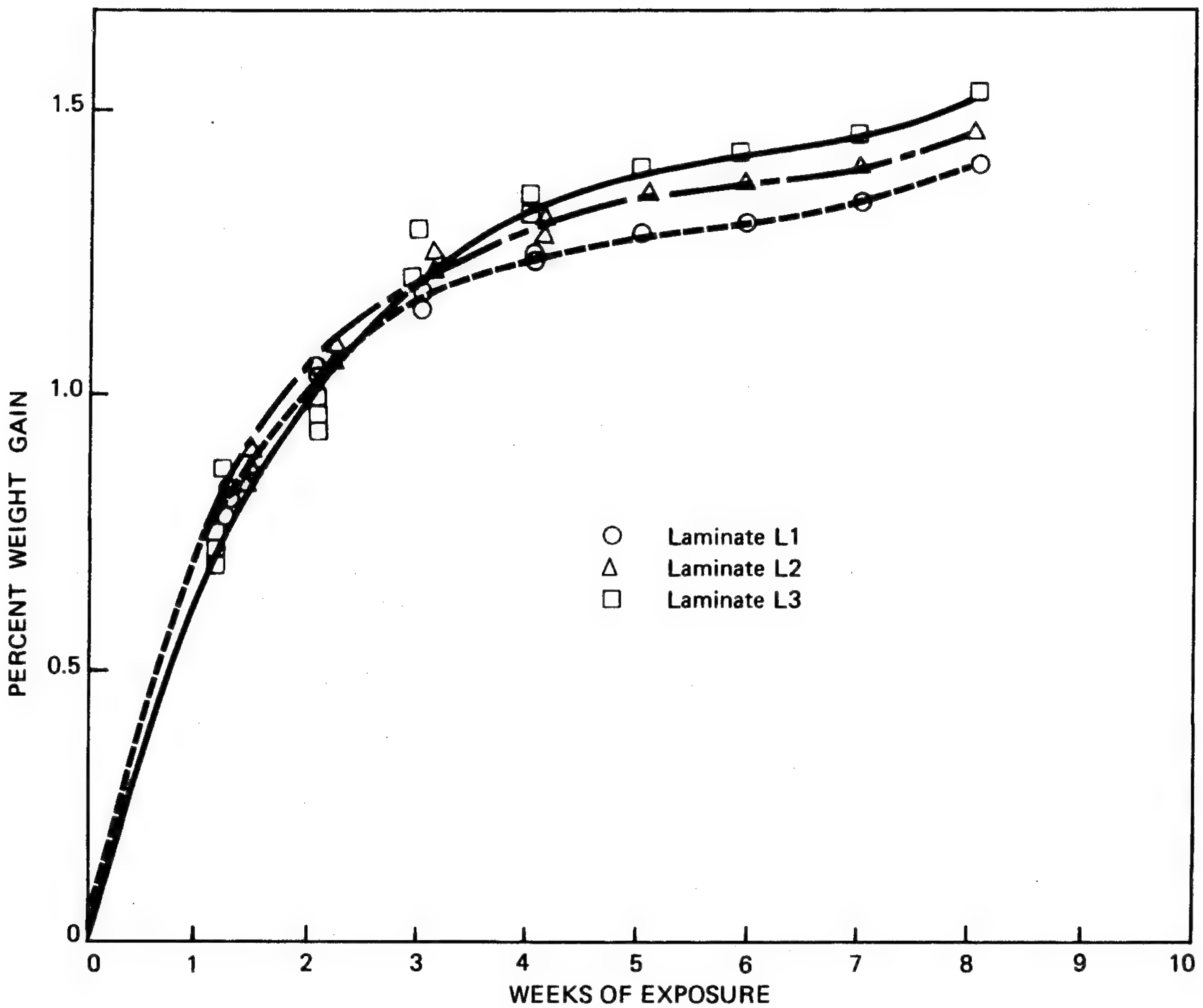


Figure 13. Weight Gain in Untabbed Static Test Laminates

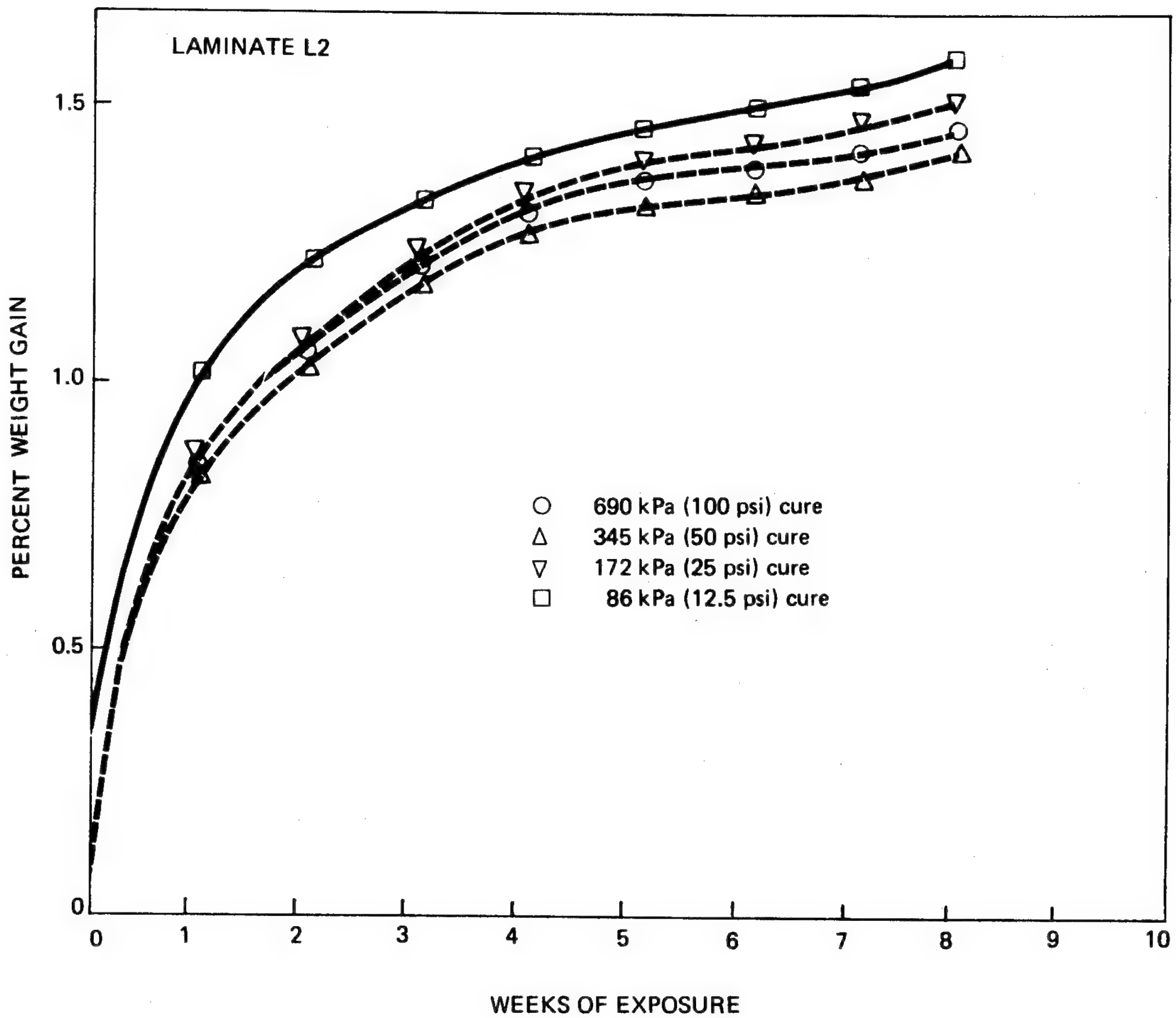


Figure 14. Weight Gain in Laminate L2 Untabbed Samples

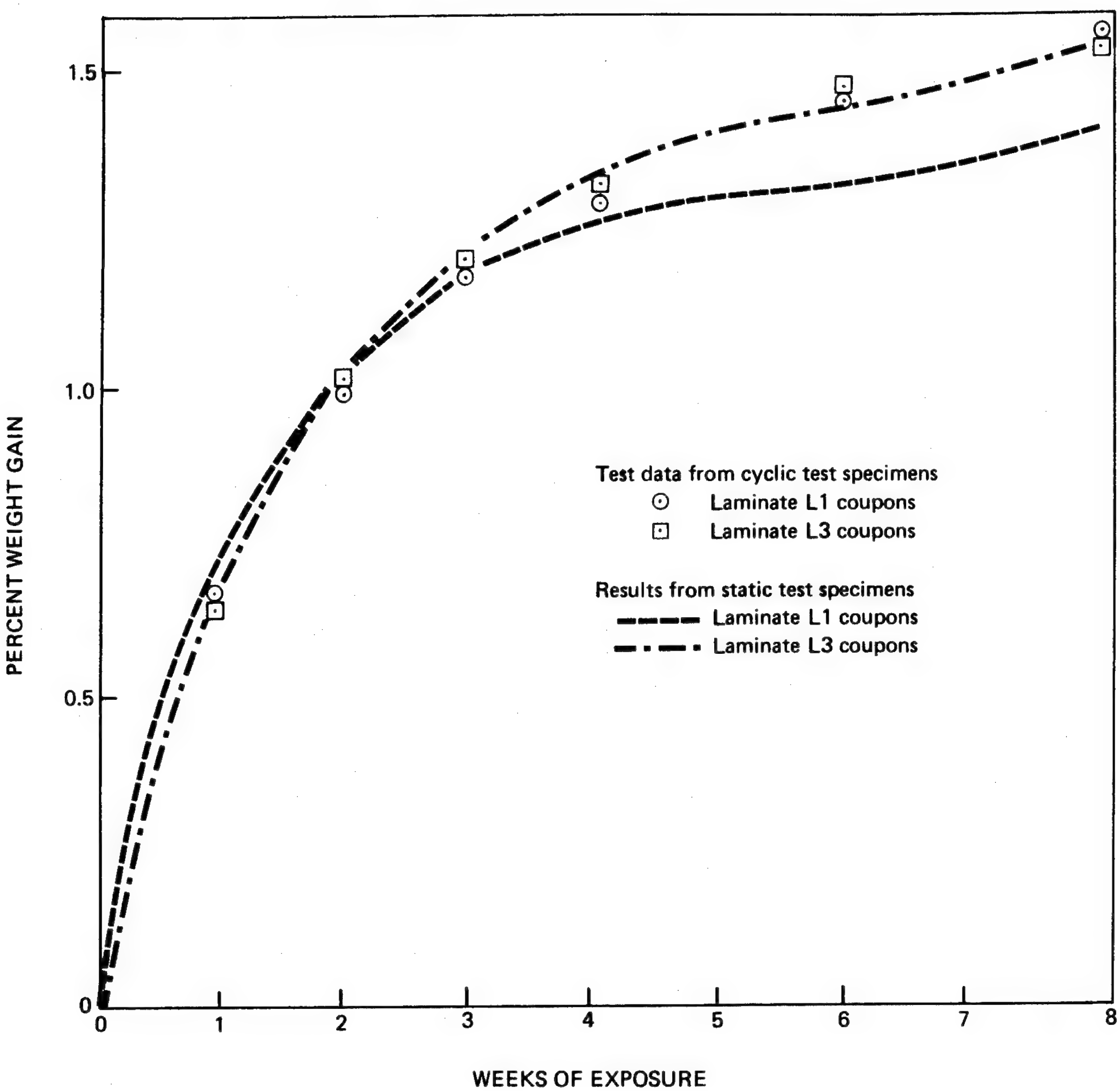


Figure 15. Weight Gain in Cyclic Test Laminates

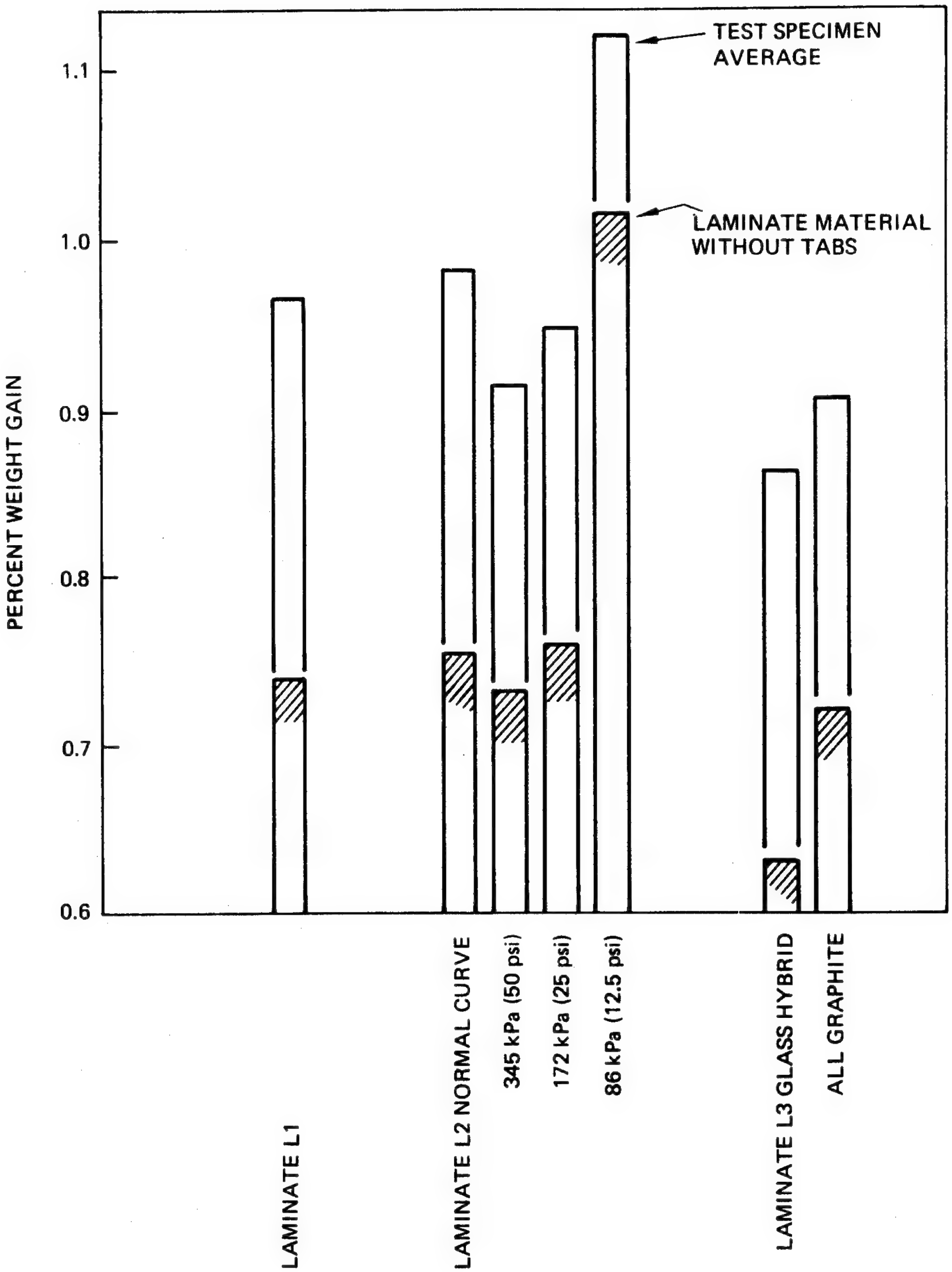


Figure 16. Weight Gain After One Week Exposure

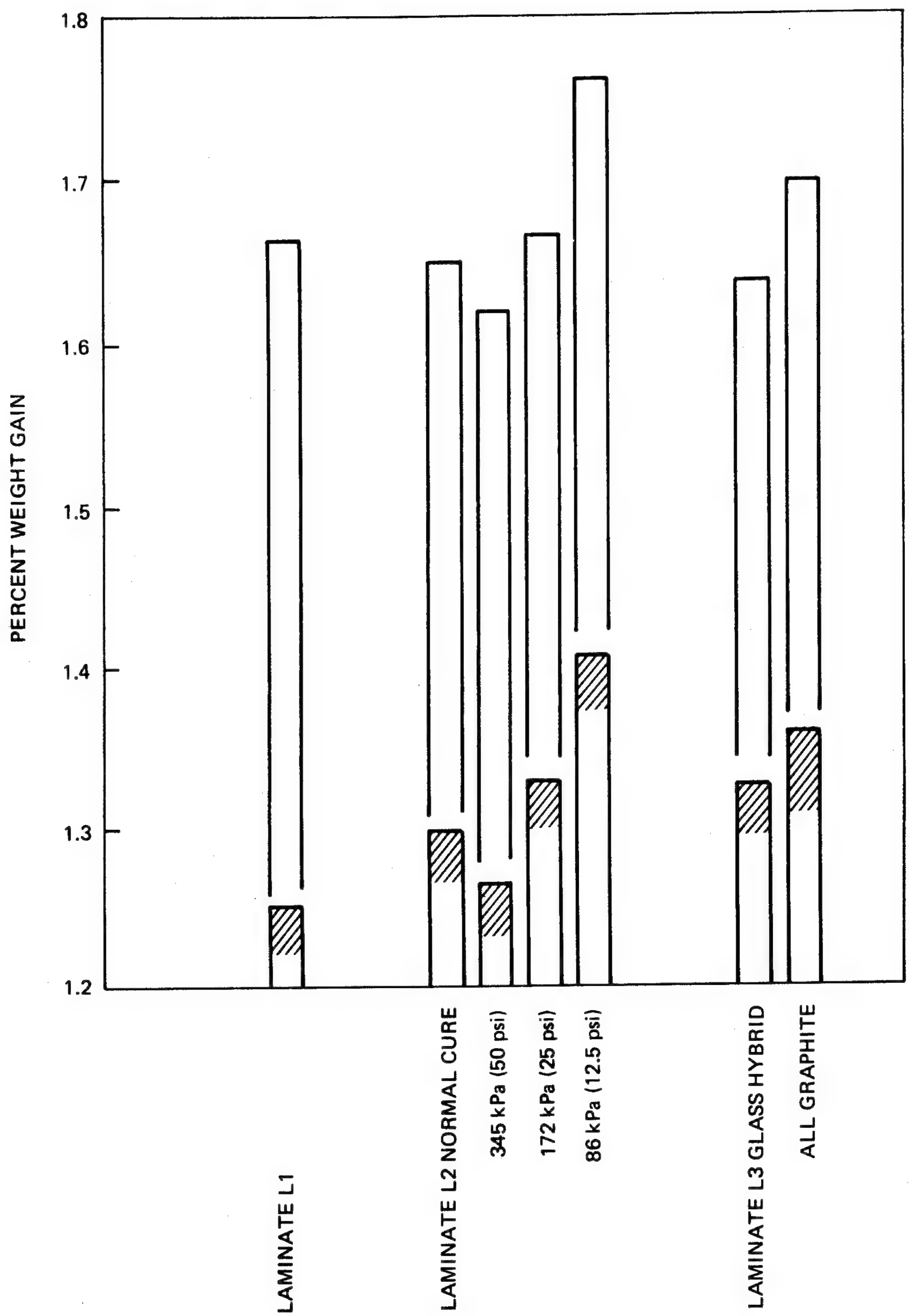


Figure 17. Weight Gain After Four Weeks Exposure

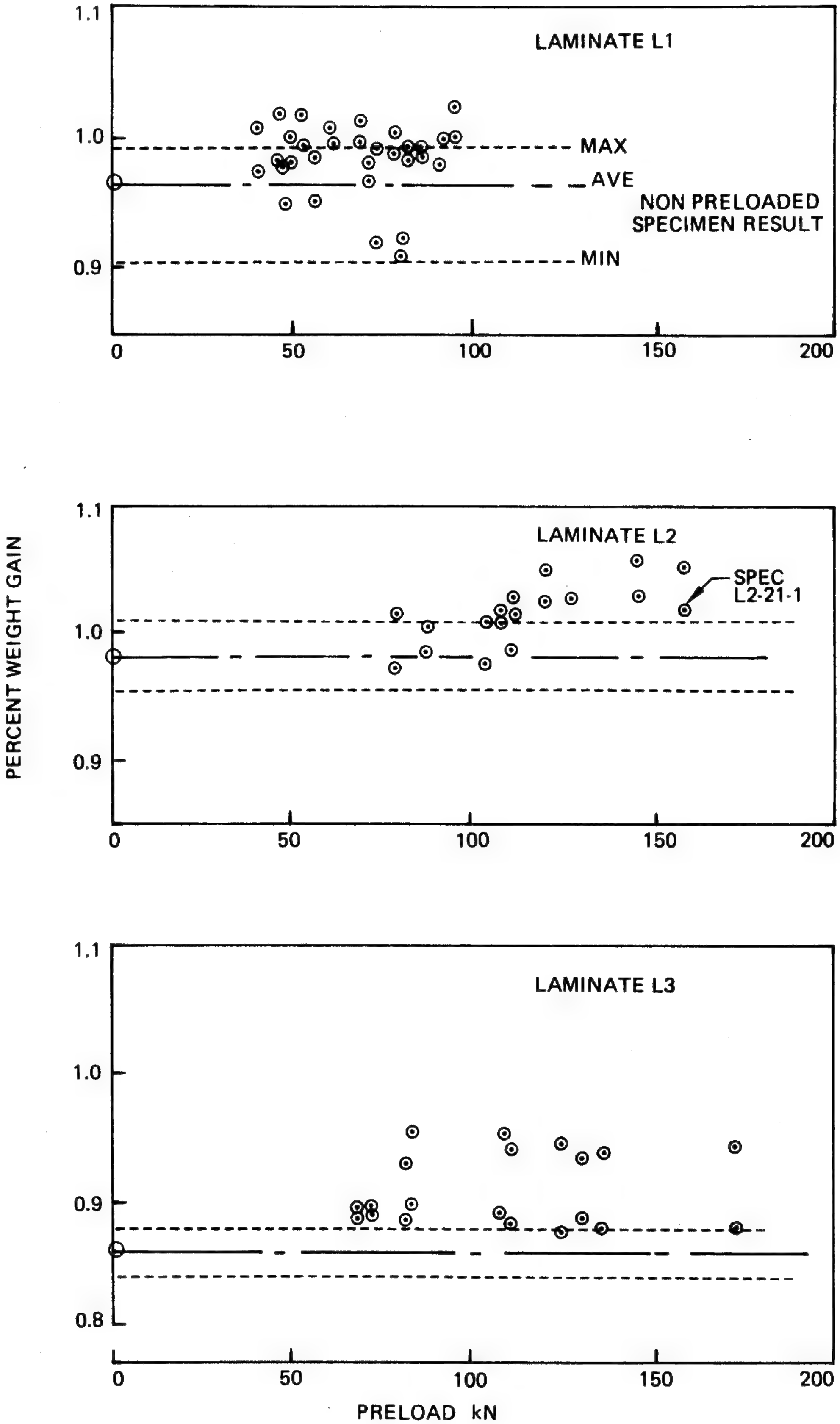


Figure 18. Influence of Preload on Weight Gain After One Week of Exposure

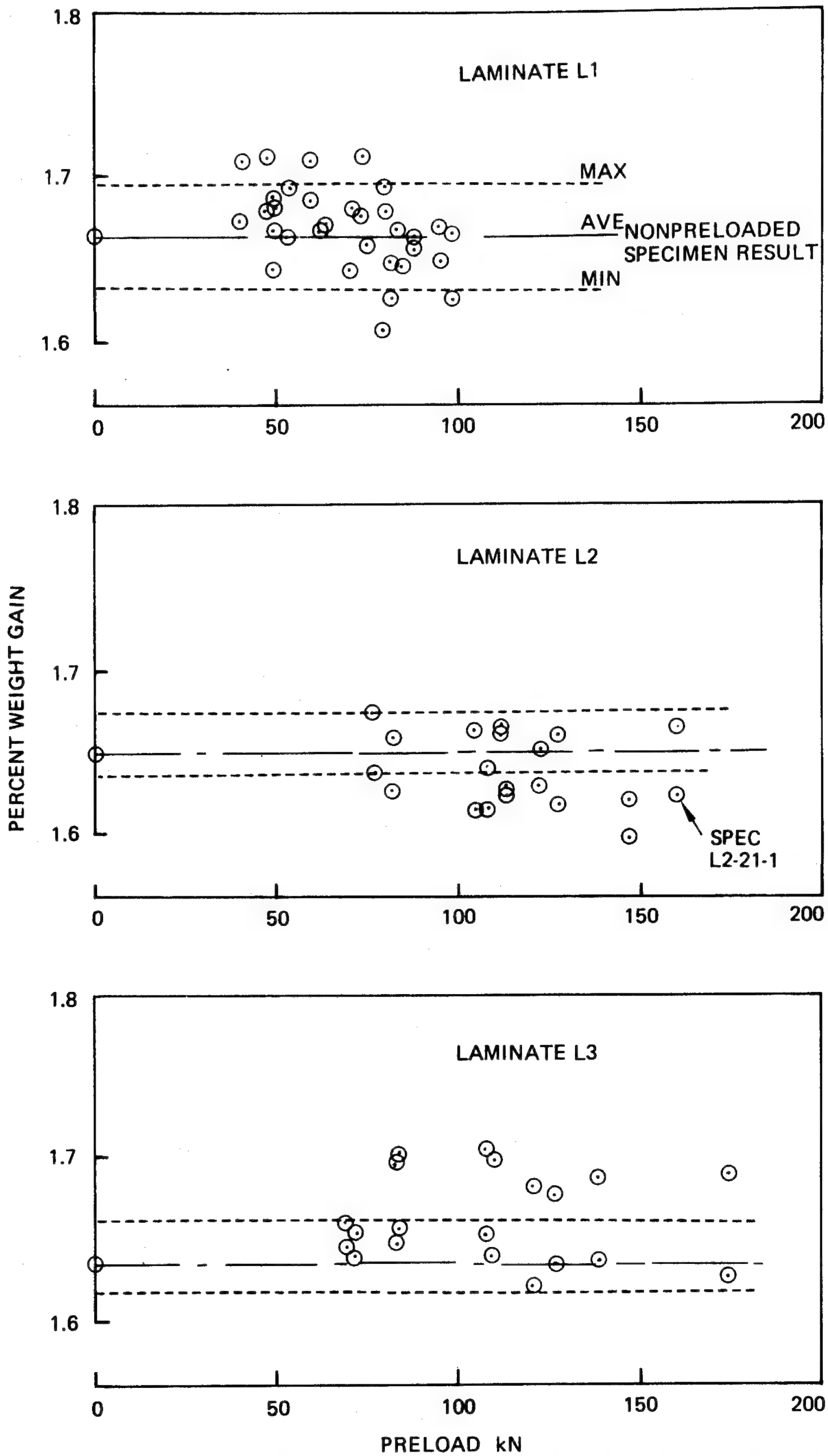


Figure 19. Influence of Preload on Weight Gain After Four Weeks of Exposure

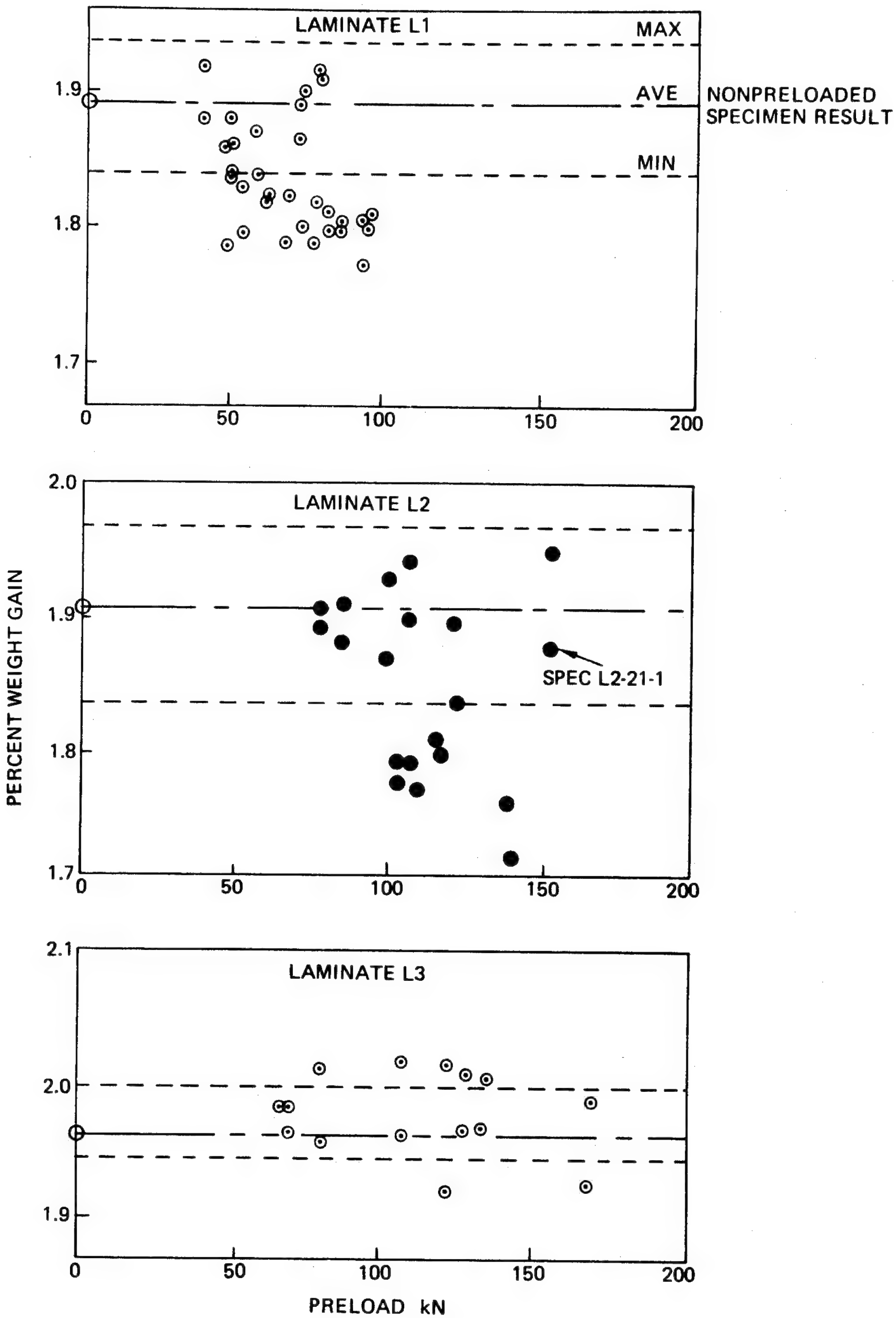


Figure 20. Influence of Preload on Weight Gain After Eight Weeks of Exposure

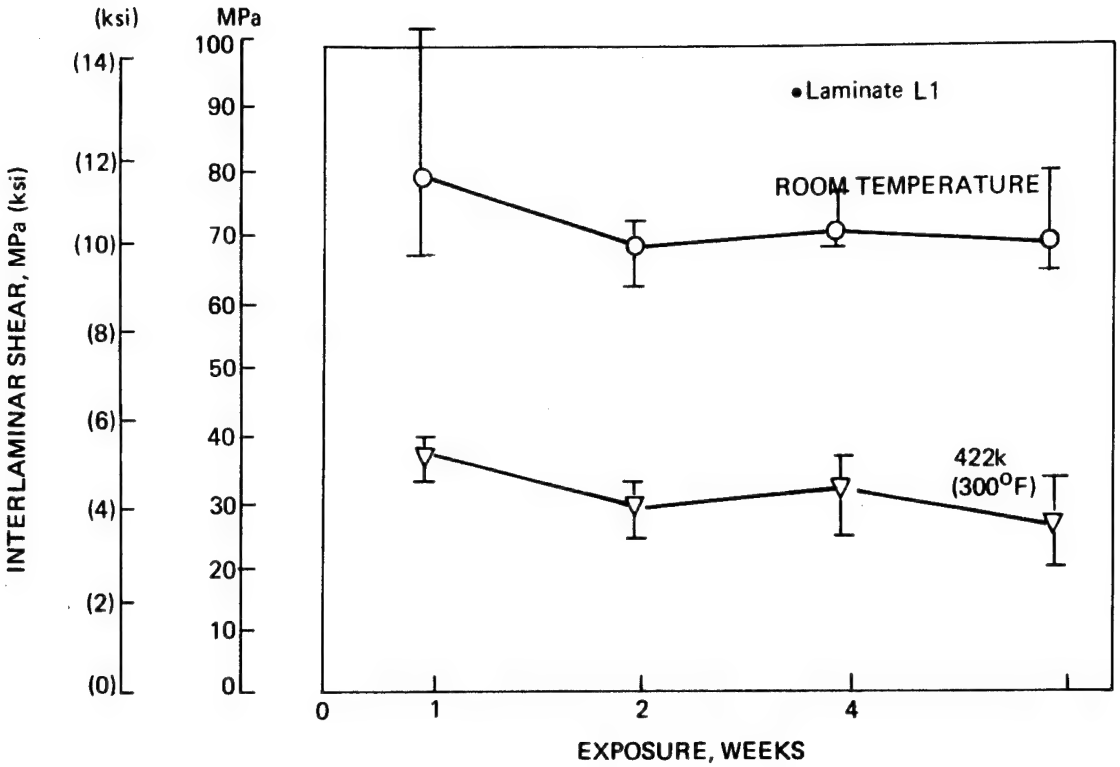


Figure 21. Influence of Moisture Exposure on Laminate L1 Shear Strength

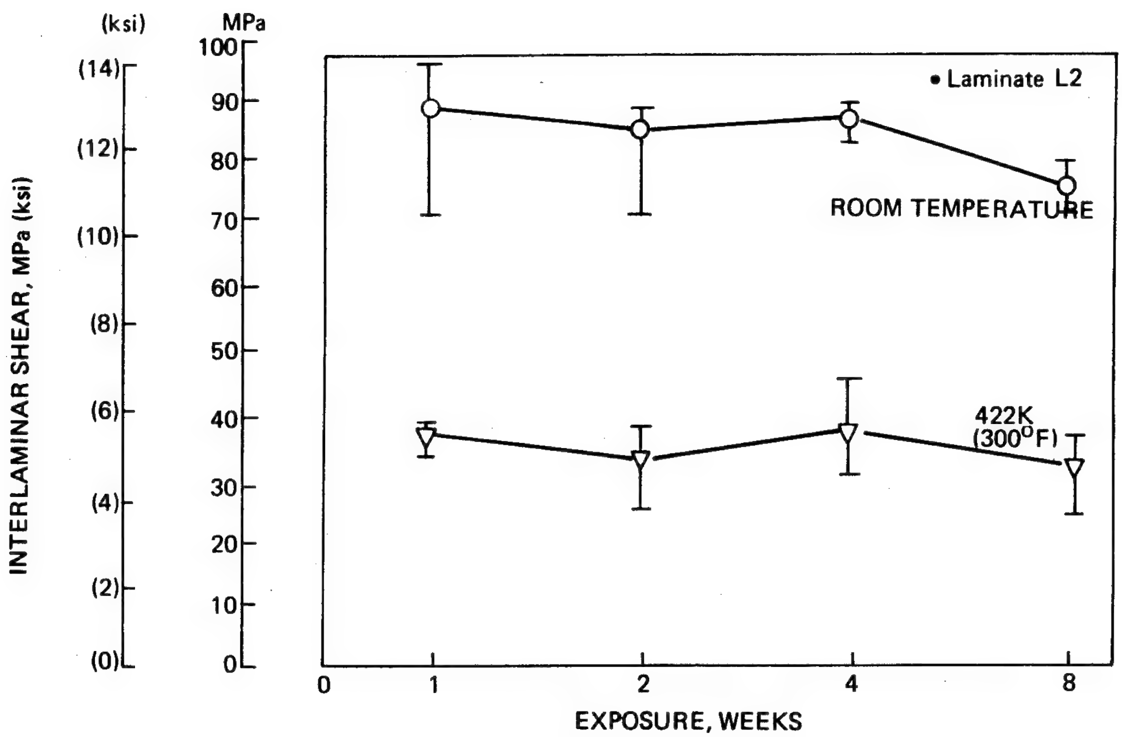


Figure 22. Influence of Moisture Exposure on Laminate L2 Shear Strength

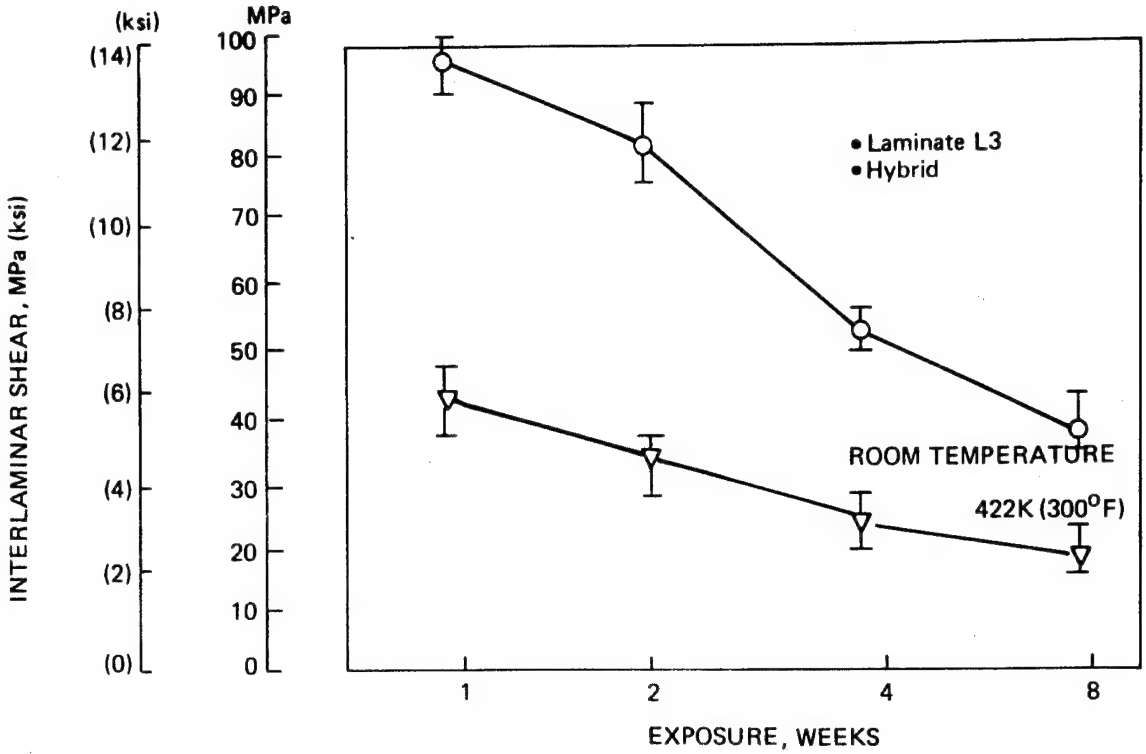


Figure 23. Influence of Moisture Exposure on Laminate L3 Shear Strength

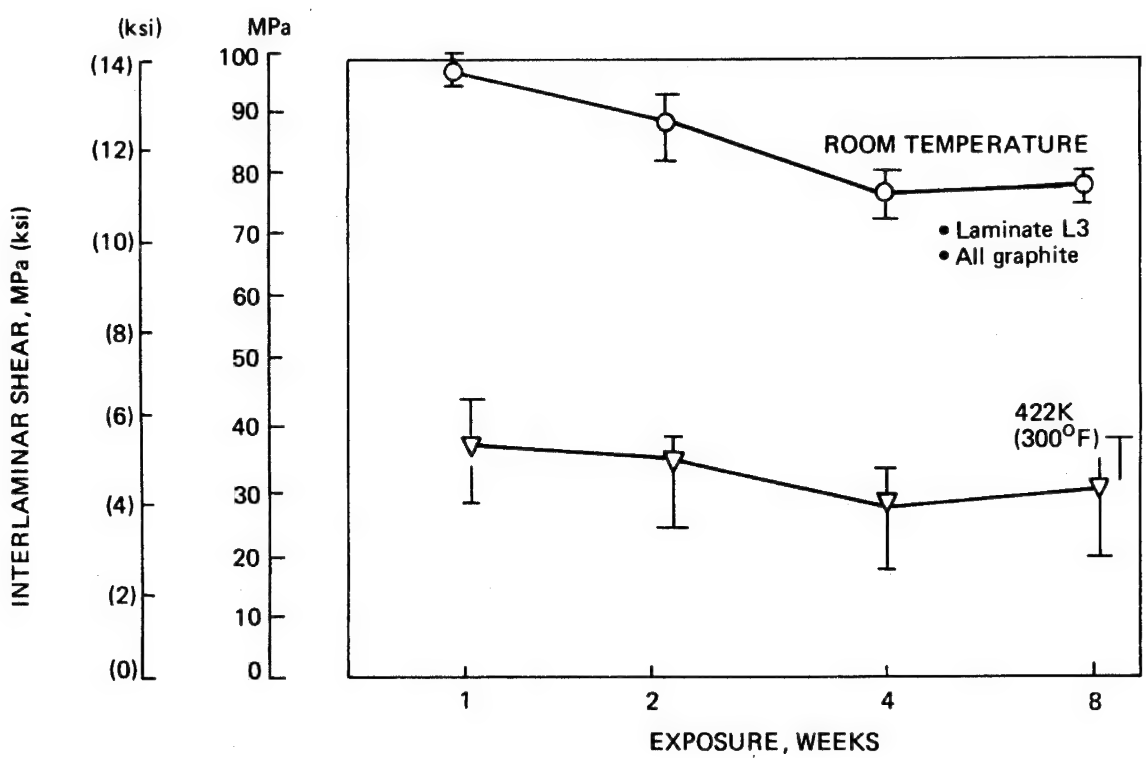


Figure 24. Influence of Moisture Exposure on All Graphite Laminate L3 Shear Strength

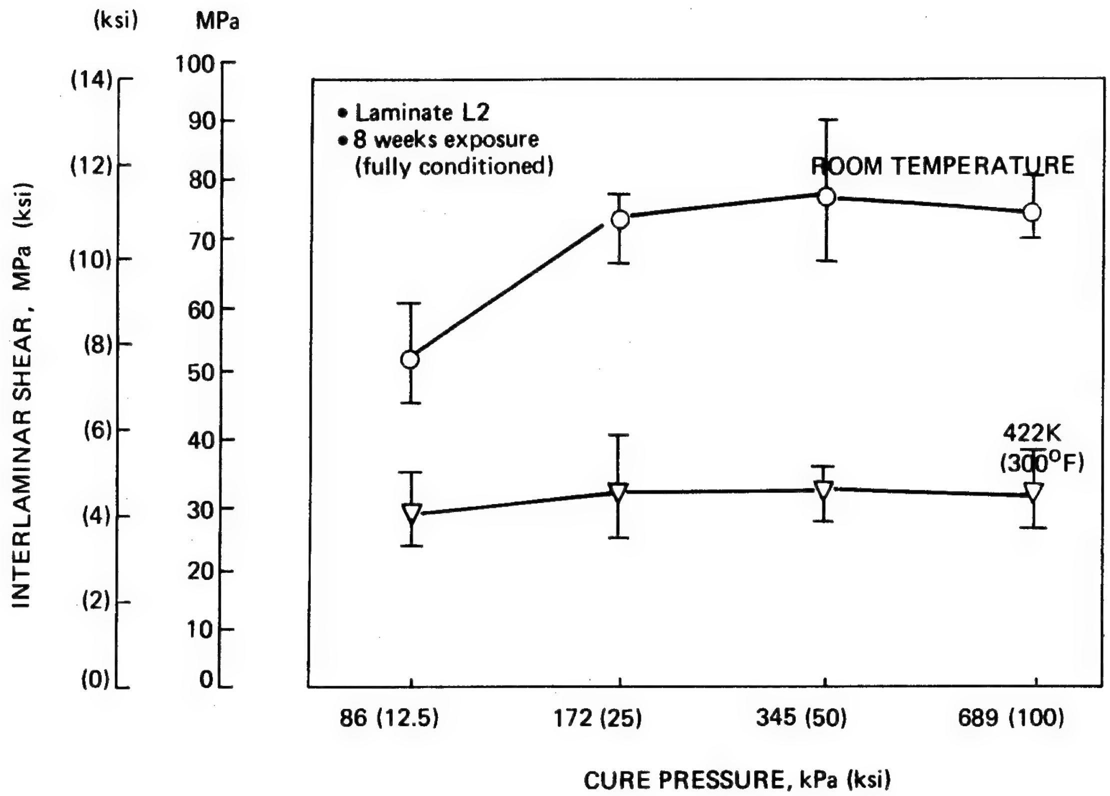


Figure 25. Influence of Cure Pressure on Laminate L2 Shear Strength

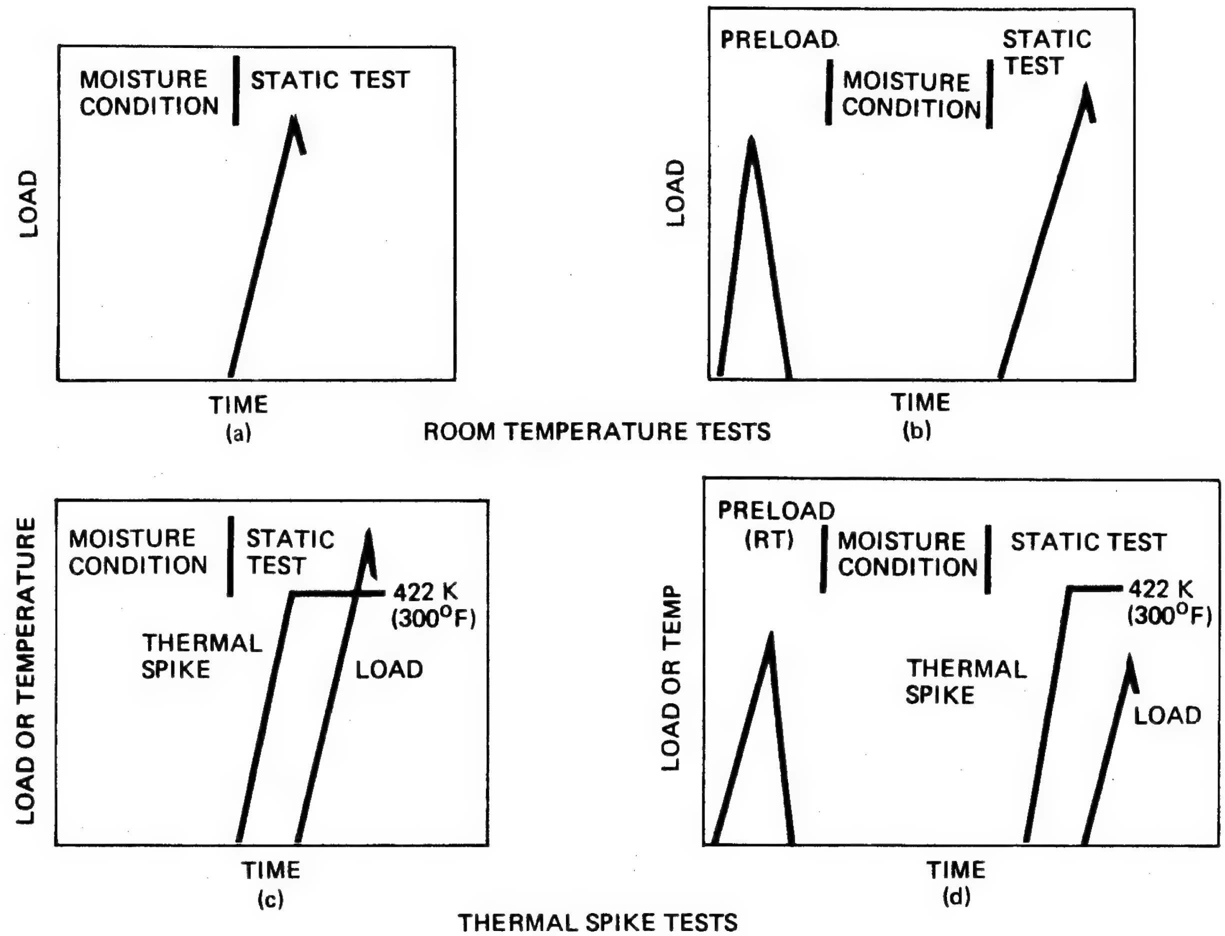


Figure 26. Static Test Load Sequences

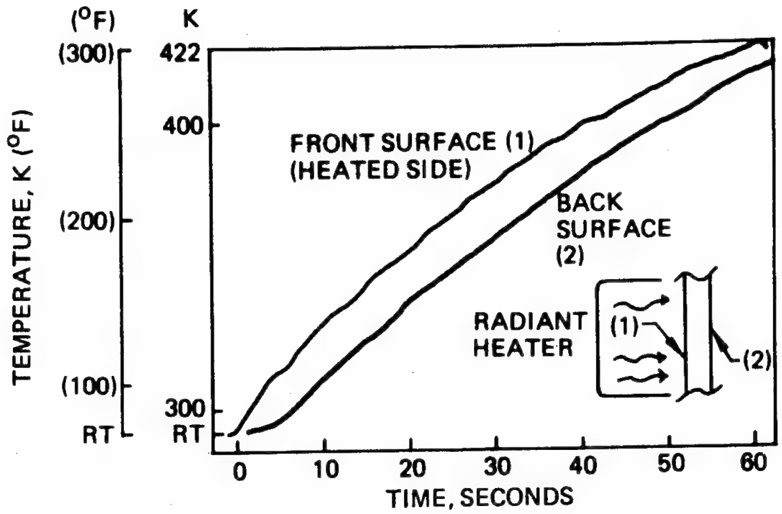


Figure 27. Front and Back Surface Temperatures for 60-Second Heatup

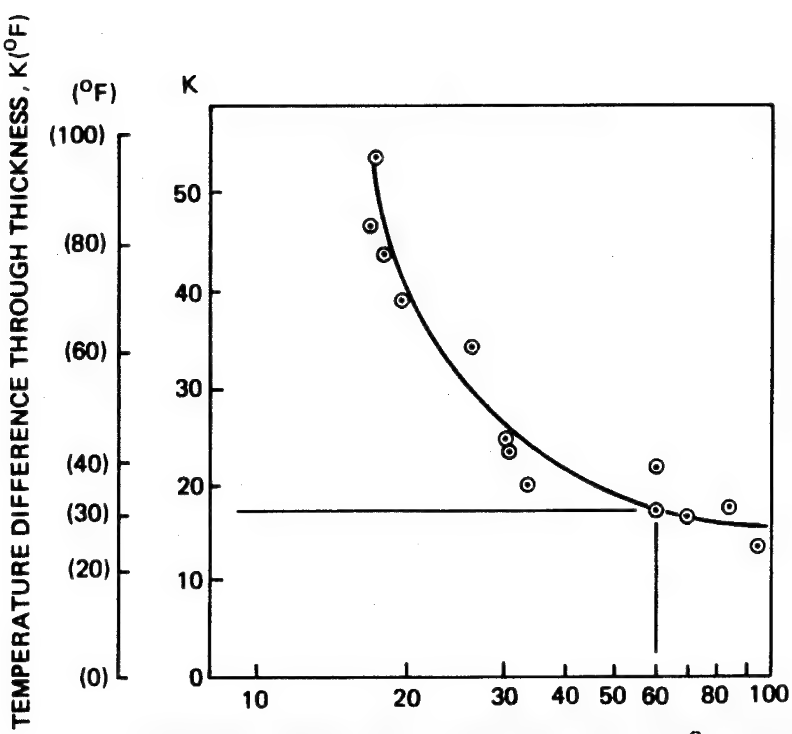


Figure 28. Through-the-Thickness Temperature Difference for Various Heating Rates

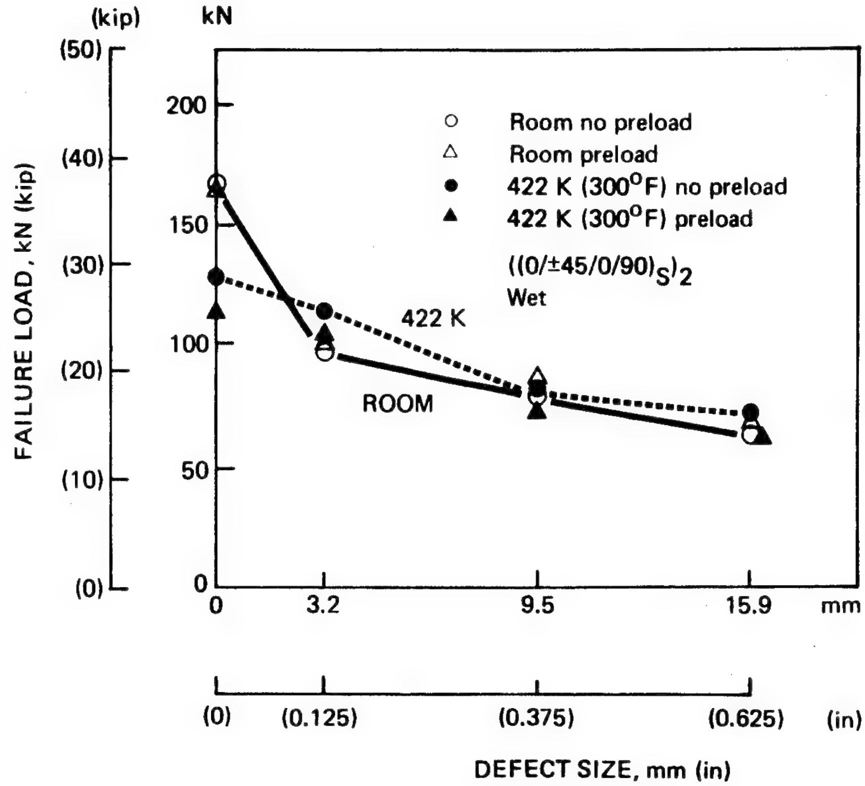


Figure 29. Laminate L1 Static Test Data (FP Slit)

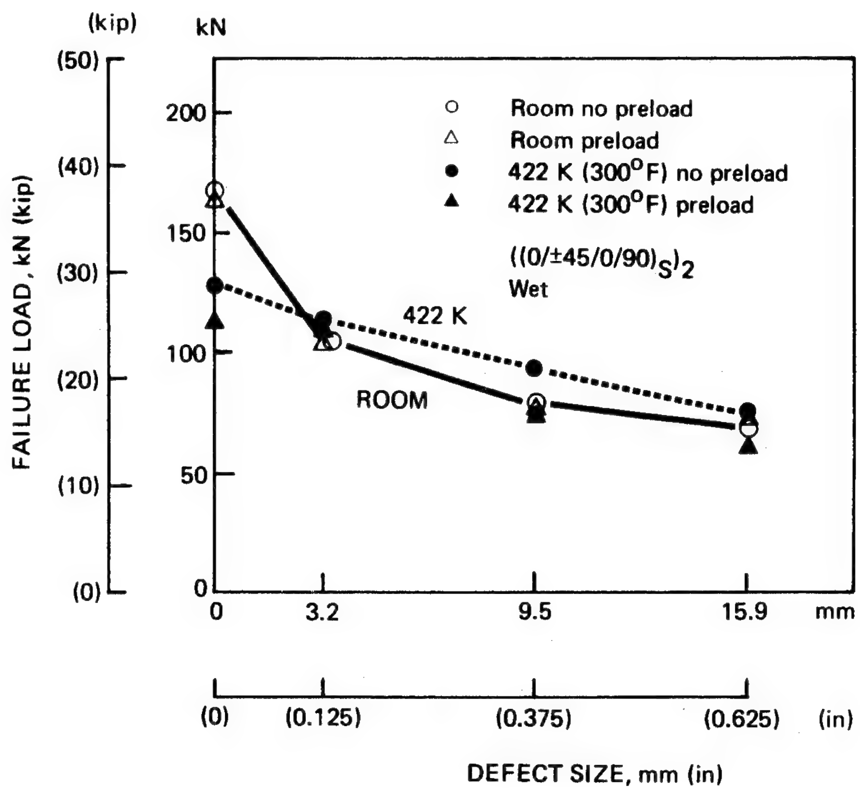


Figure 30. Laminate L1 Static Test Data (FP Hole)

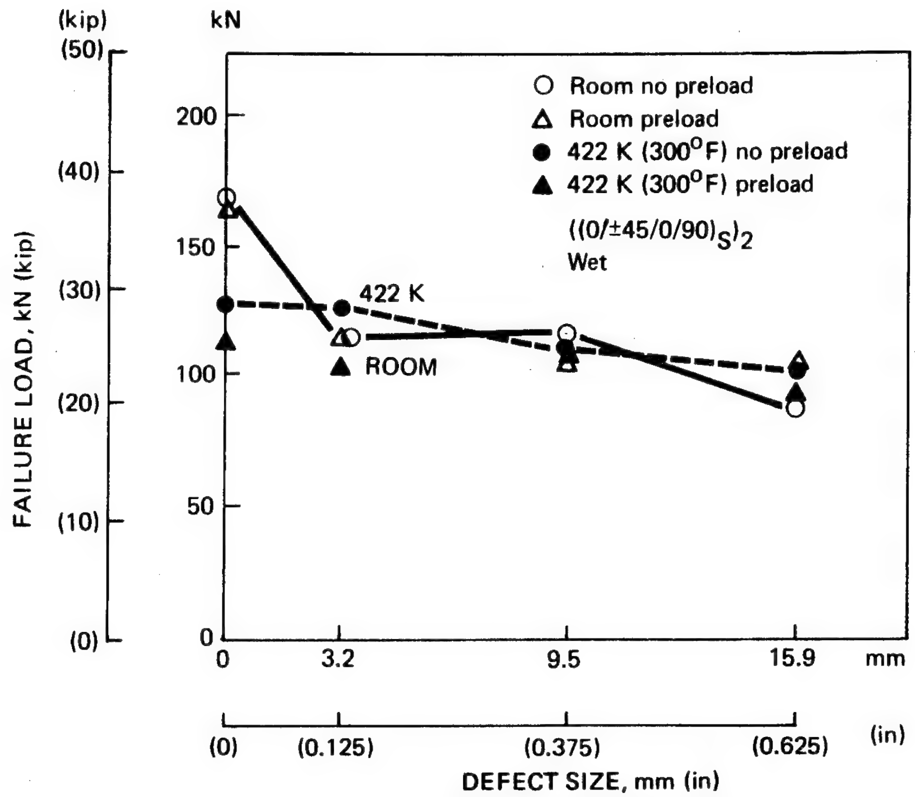


Figure 31. Laminate L1 Static Test Data (HP Slit)

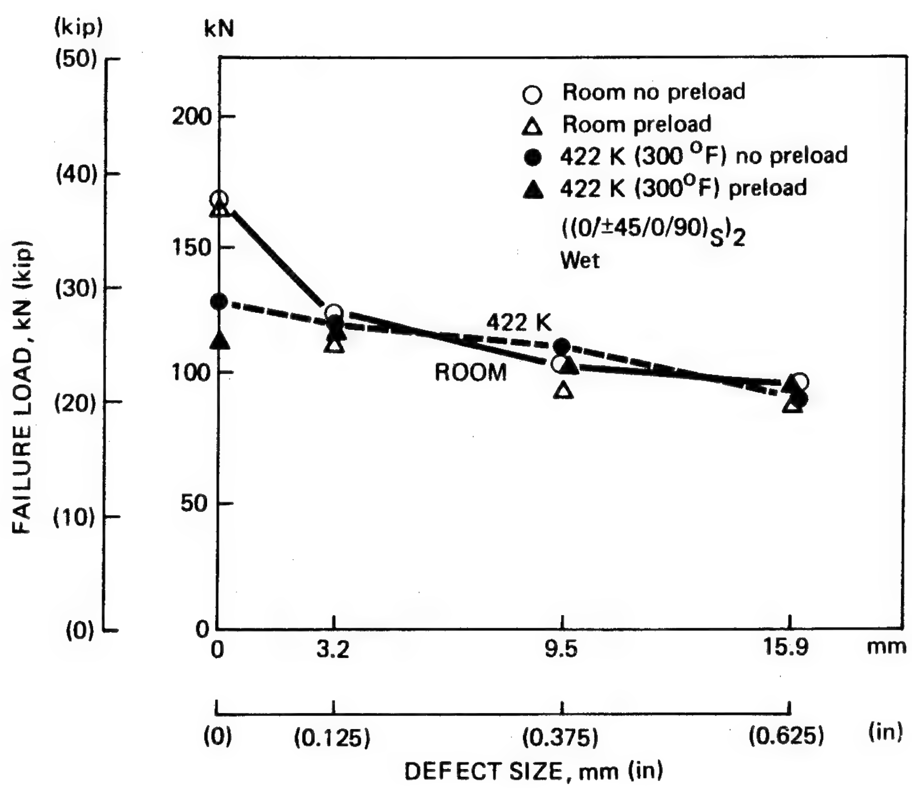


Figure 32. Laminate L1 Static Test Data (HP Hole)

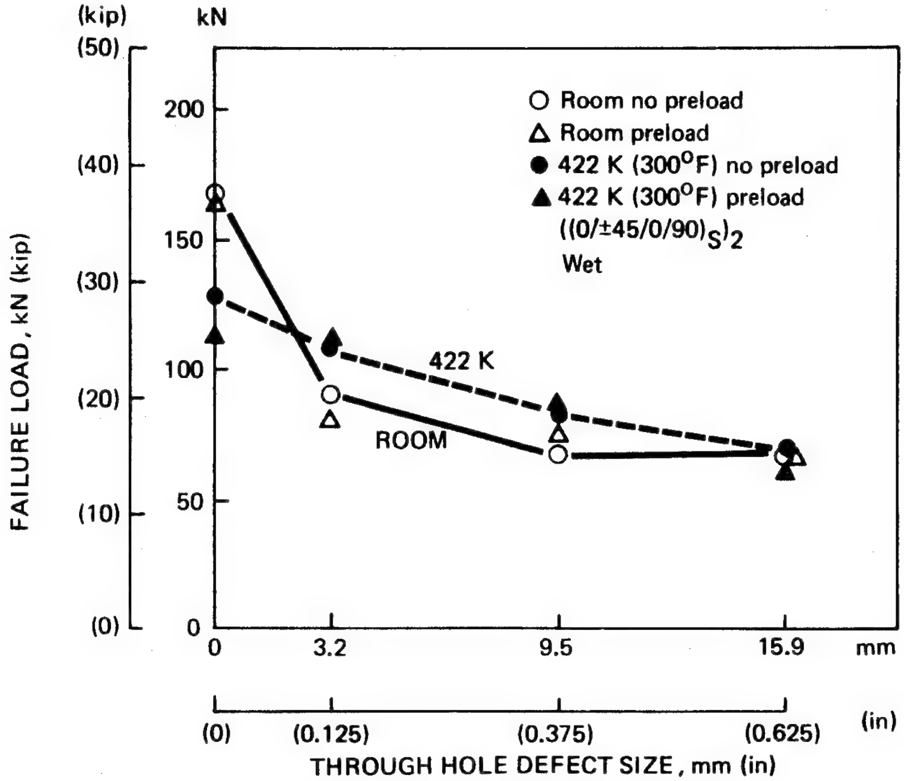


Figure 33. Laminate L1 Static Test Data (CSK Hole)

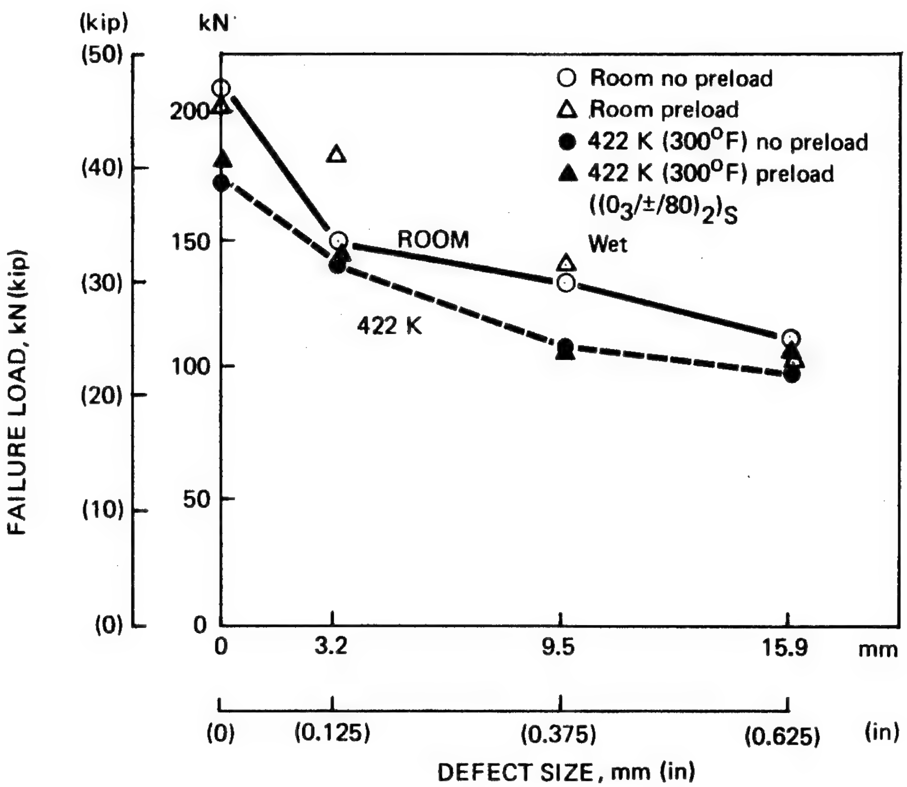


Figure 34. Laminate L2 Static Test Data (FP Slit)

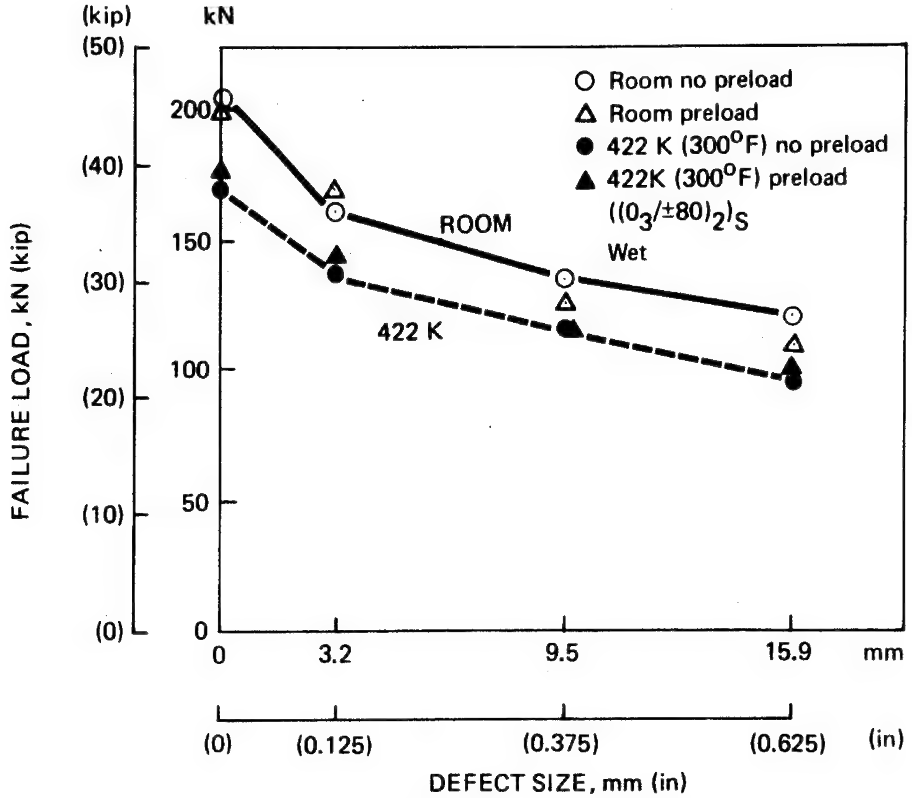


Figure 35. Laminate L2 Static Test Data (FP Hole)

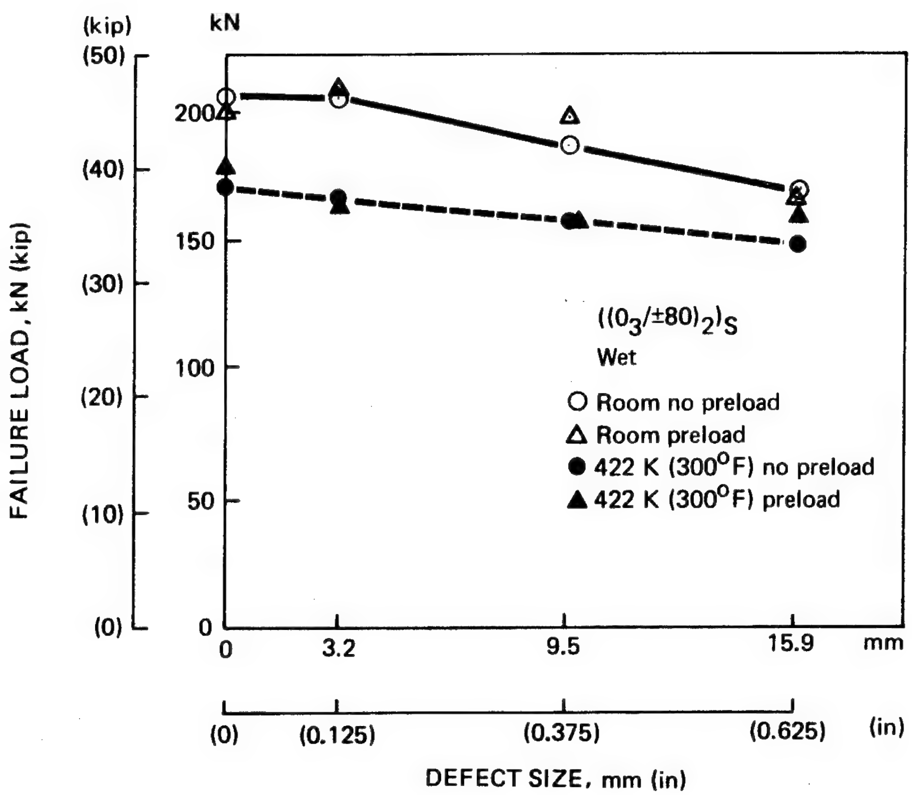


Figure 36. Laminate L2 Static Test Data (HP Slit)

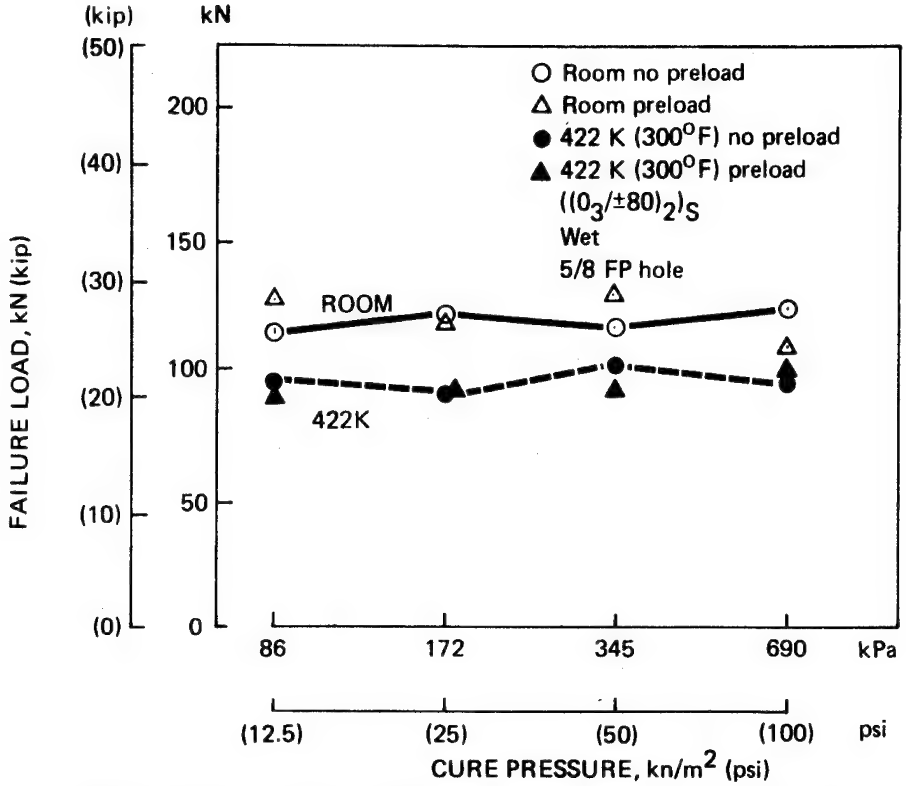


Figure 37. Laminate L2 Static Test Data (Low Cure Pressure)

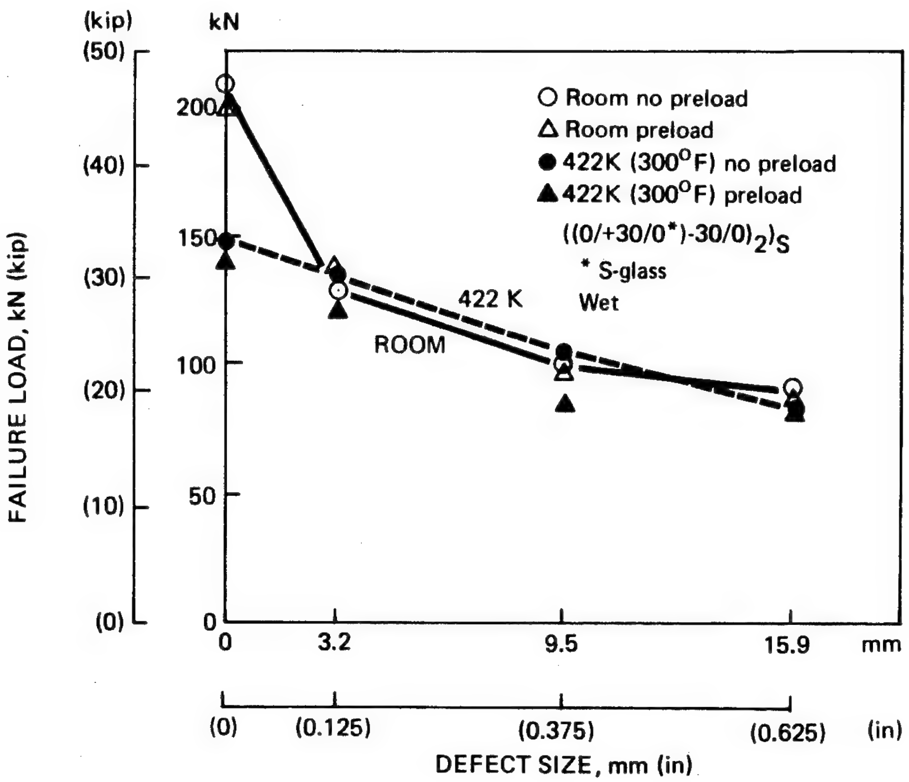


Figure 38. Laminate L3 Static Test Data (FP Slit)

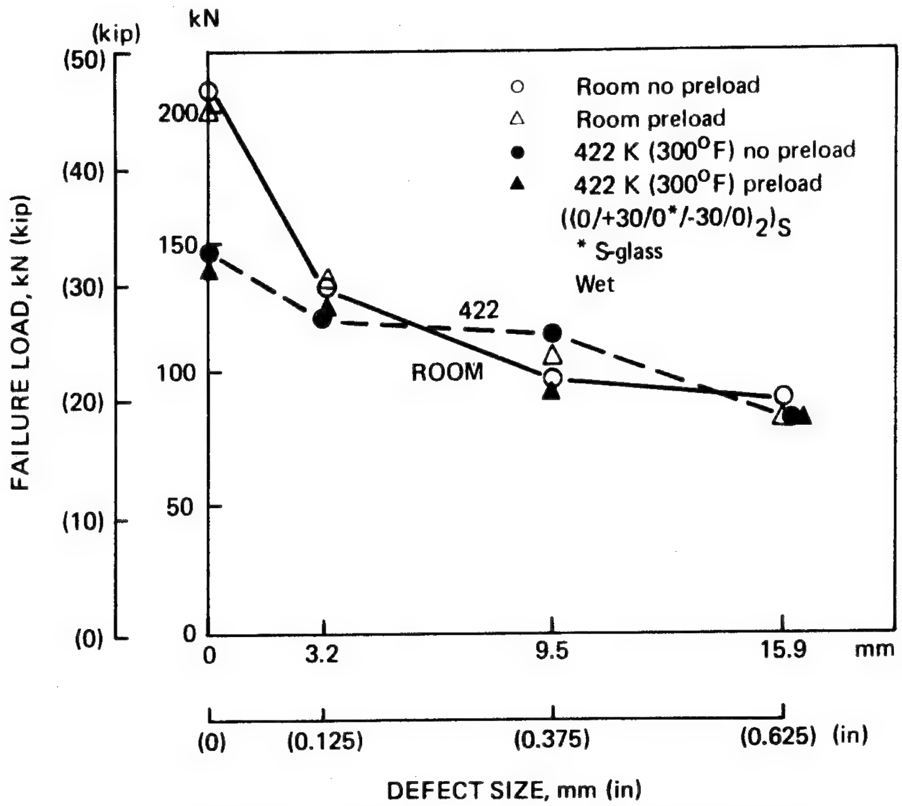


Figure 39. Laminate L3 Static Test Data (FP Hole)

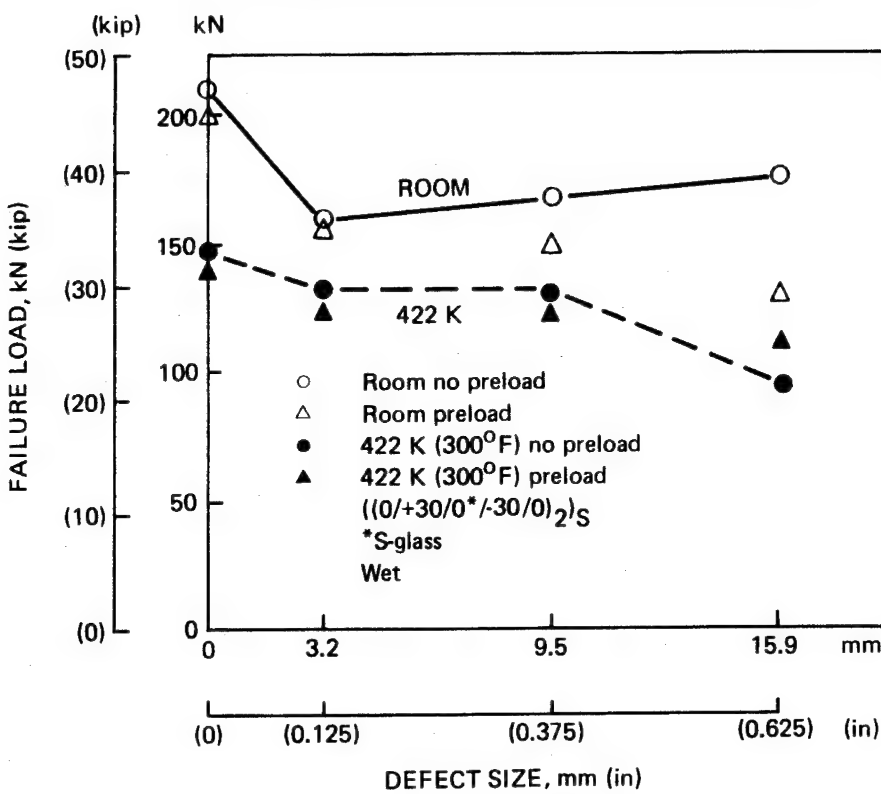


Figure 40. Laminate L3 Static Test Data (HP Slit)

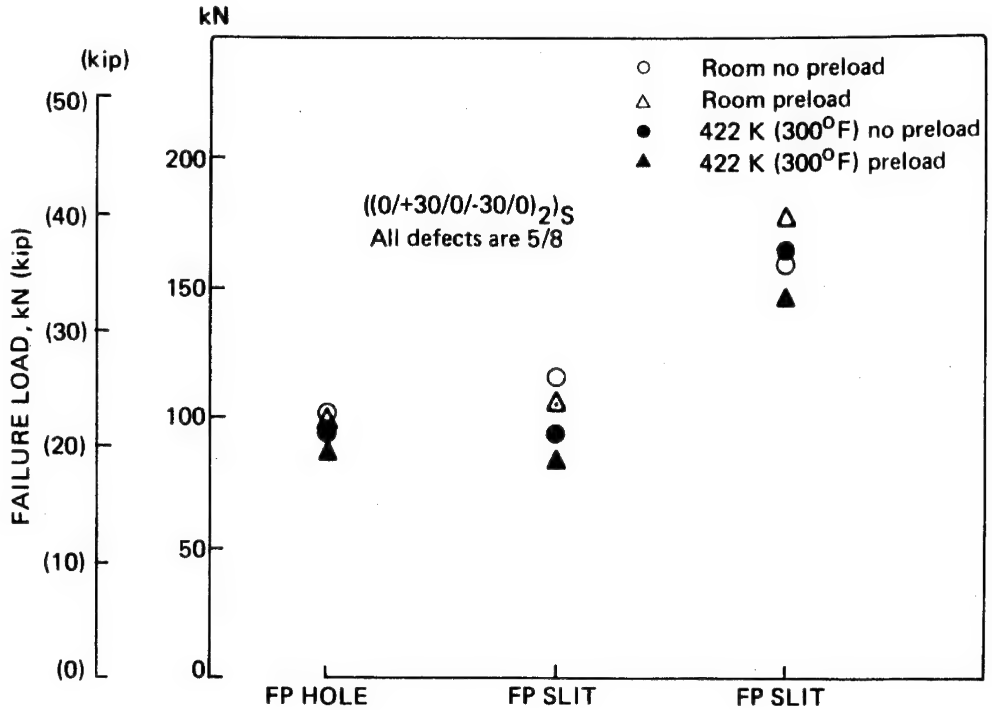


Figure 41. Laminate L3 Static Test Data (All Graphite Laminate)

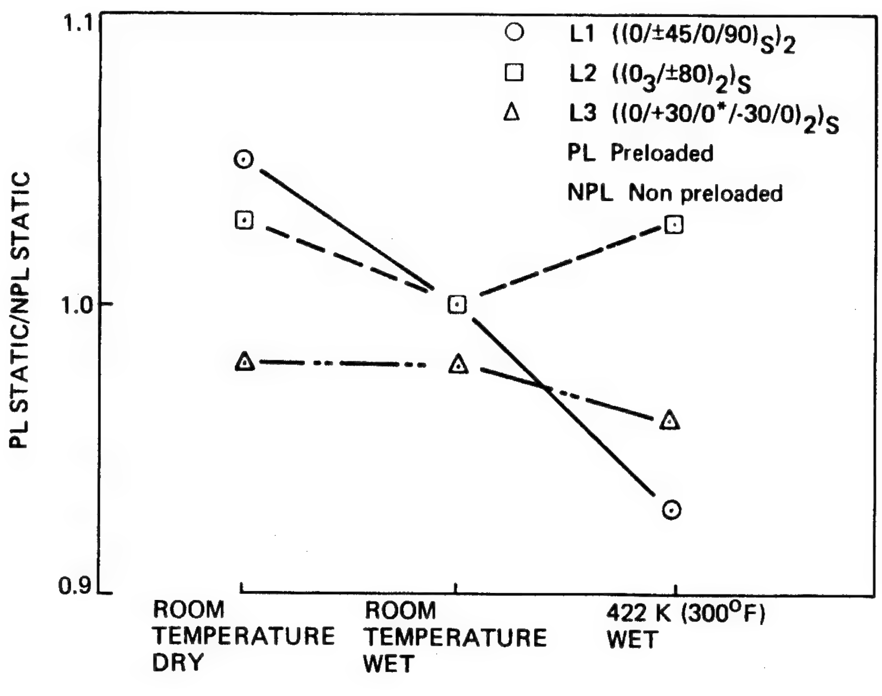


Figure 42. Average Ratio of PL to NPL Specimen Fracture Strength

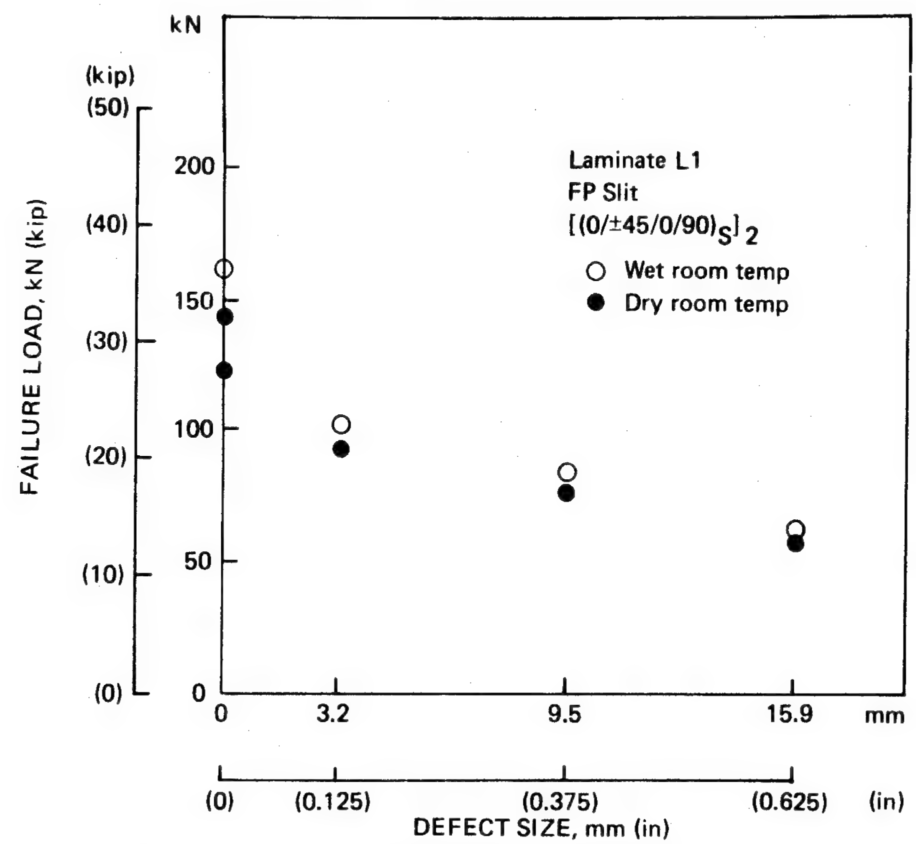


Figure 43. Effect of Moisture on Laminate L1 Fracture (FP Slit)

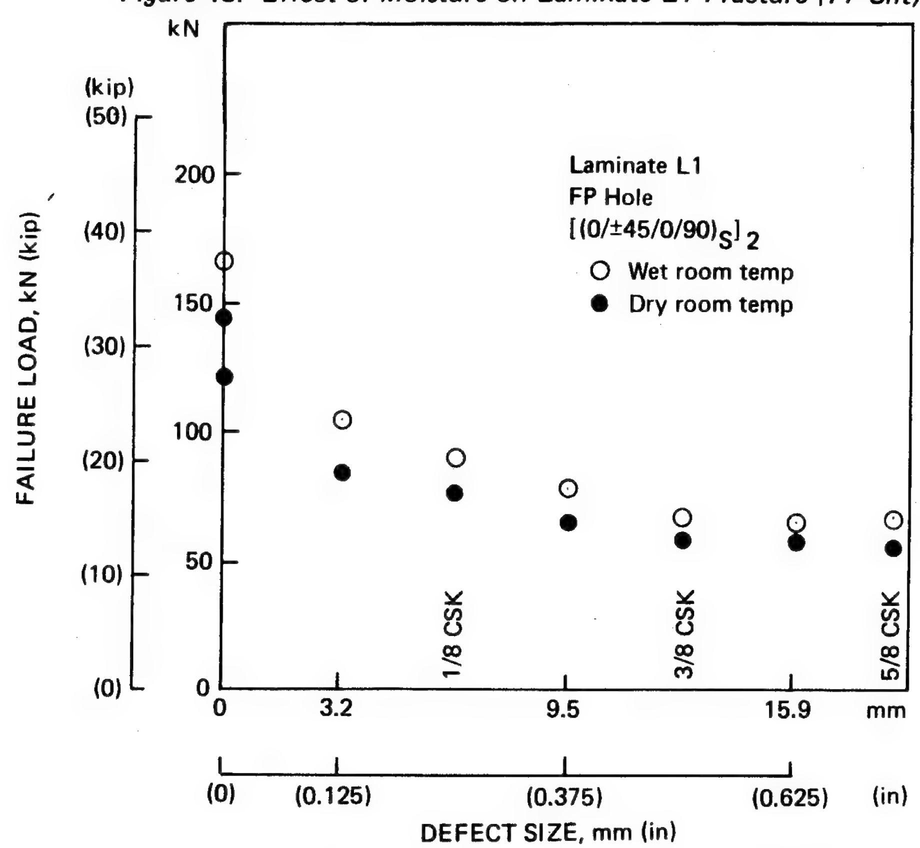


Figure 44. Effect of Moisture on Laminate L1 Fracture (FP Hole)

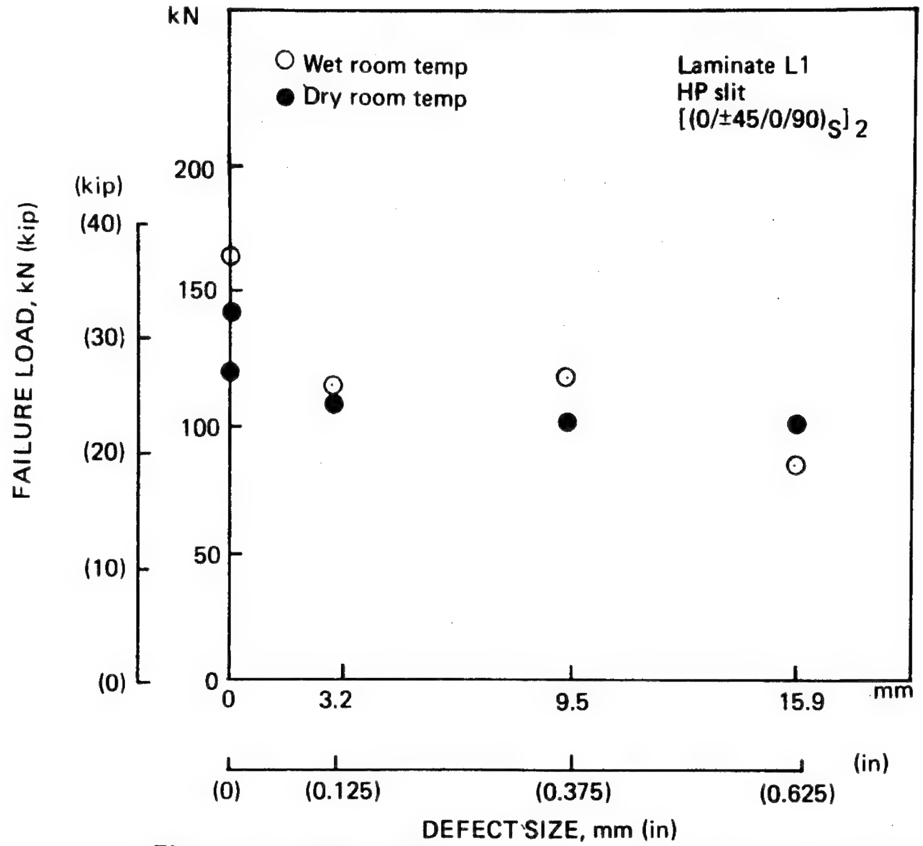


Figure 45. Effect of Moisture on Laminate L1 Fracture (HP Slit)

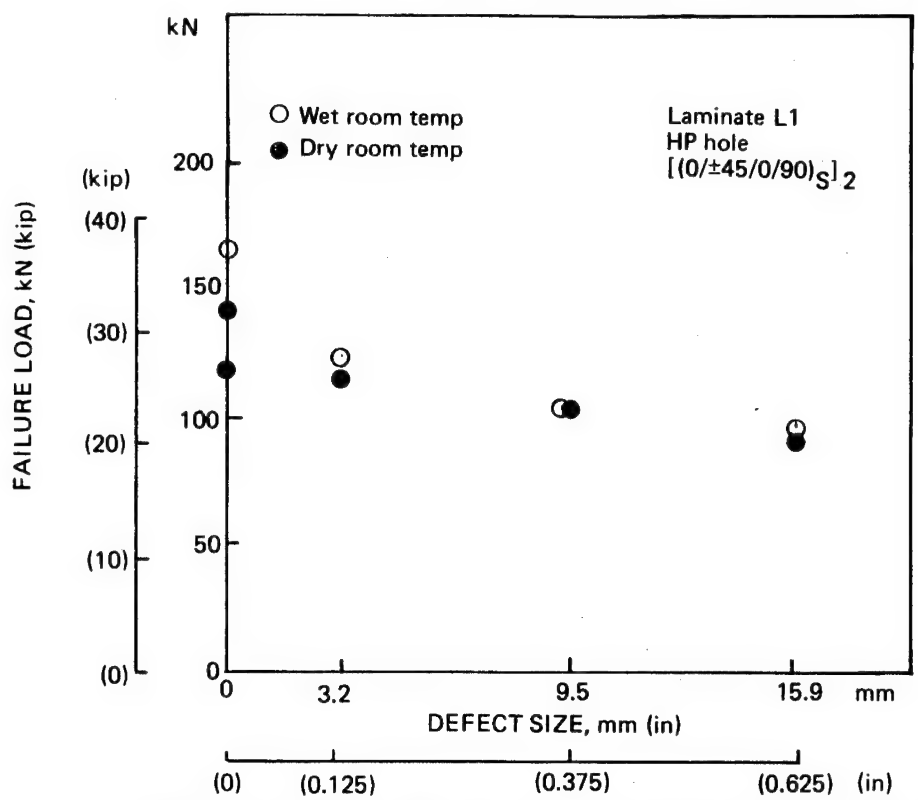


Figure 46. Effect of Moisture on Laminate L1 Fracture (HP Hole)

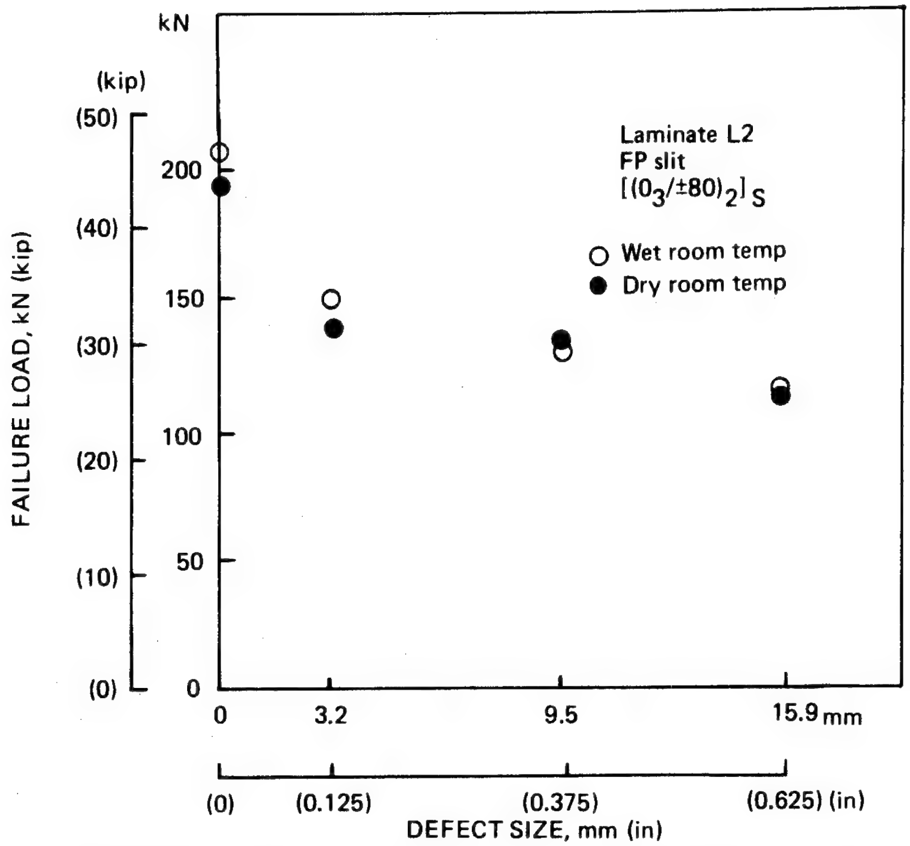


Figure 47. Effect of Moisture on Laminate L2 Fracture (FP Slit)

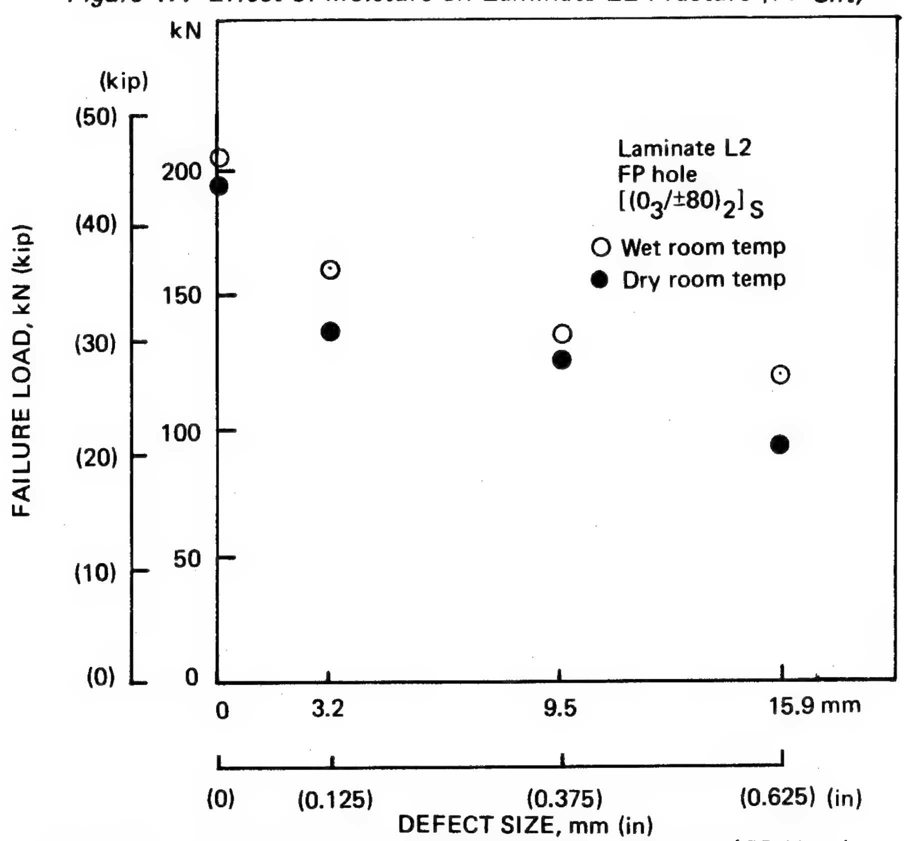


Figure 48. Effect of Moisture on Laminate L2 Fracture (FP Hole)

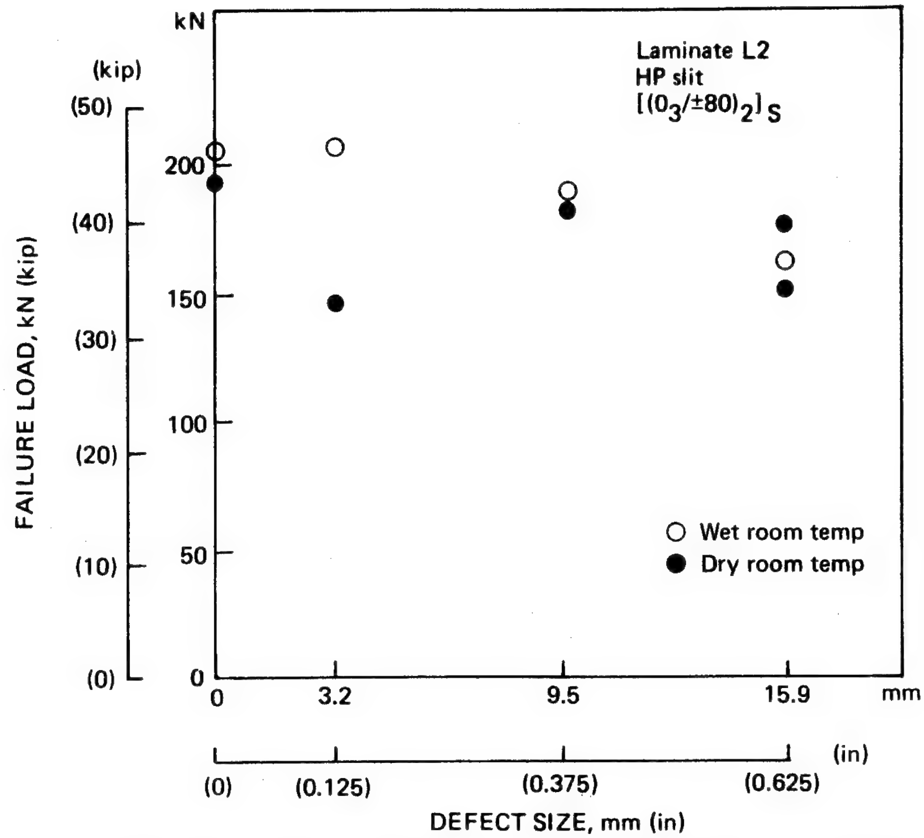


Figure 49. Effect of Moisture on Laminate L2 Fracture (HP Slit)

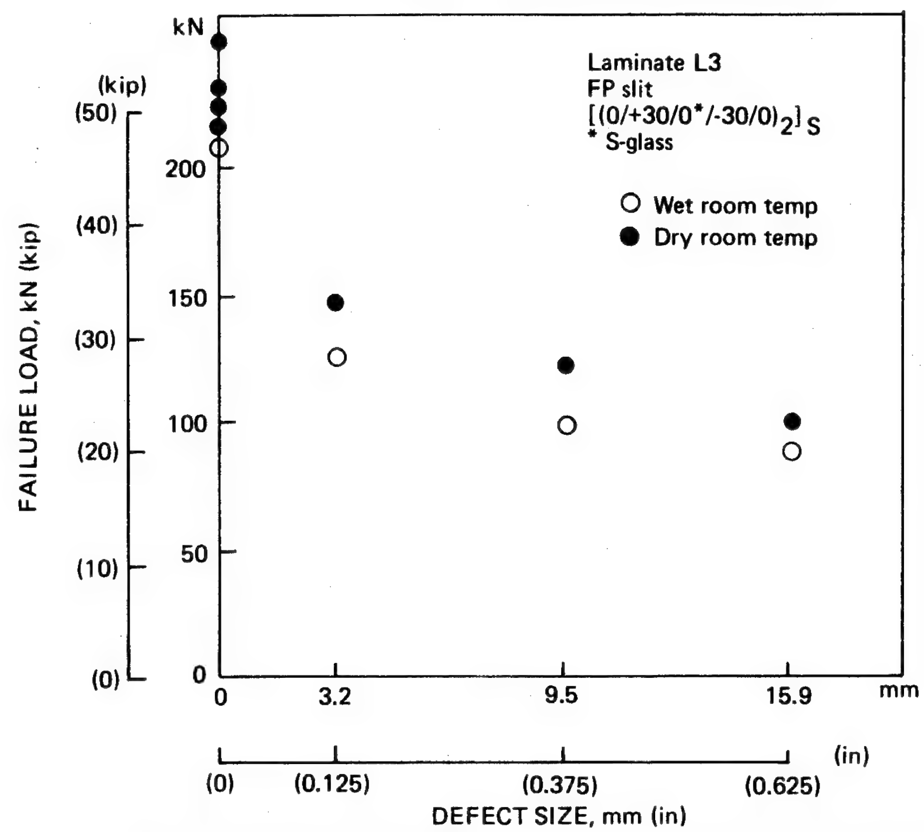


Figure 50. Effect of Moisture on Laminate L3 Fracture (FP Slit)

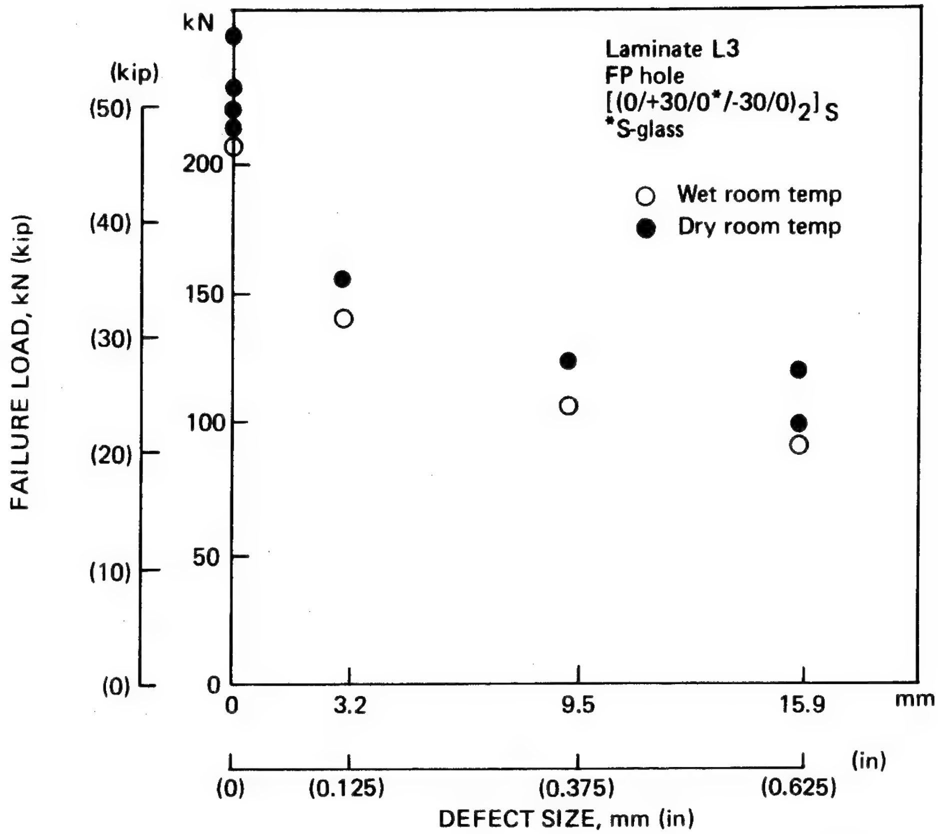


Figure 51. Effect of Moisture on Laminate L3 Fracture (FP Hole)

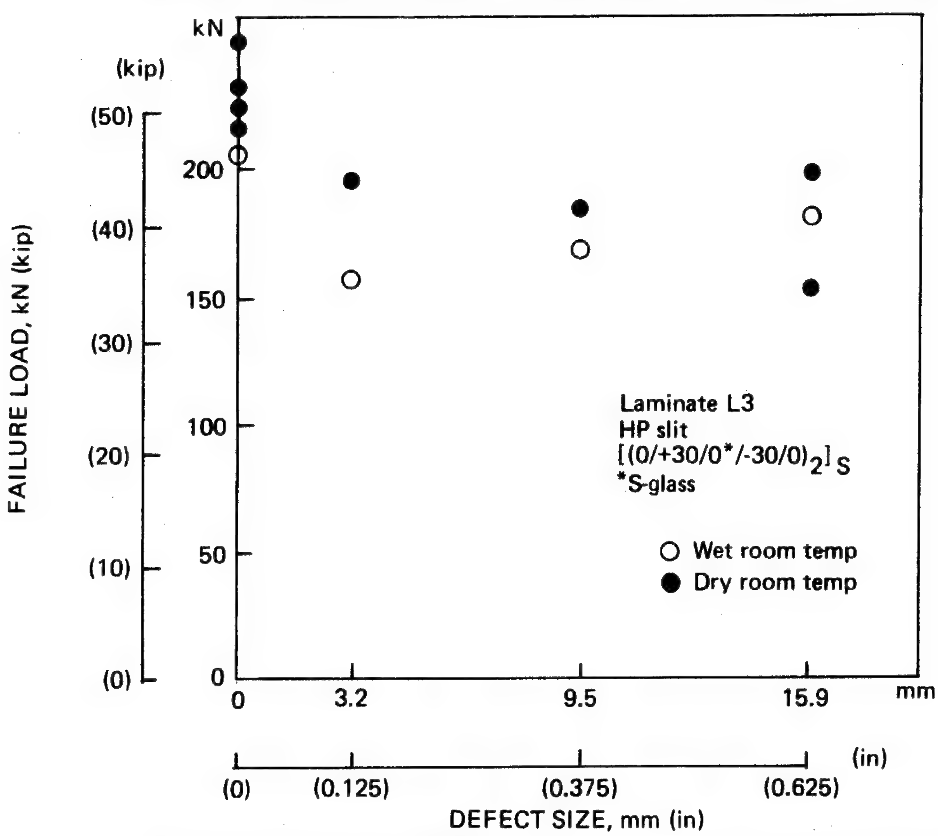


Figure 52. Effect of Moisture on Laminate L3 Fracture (HP Slit)

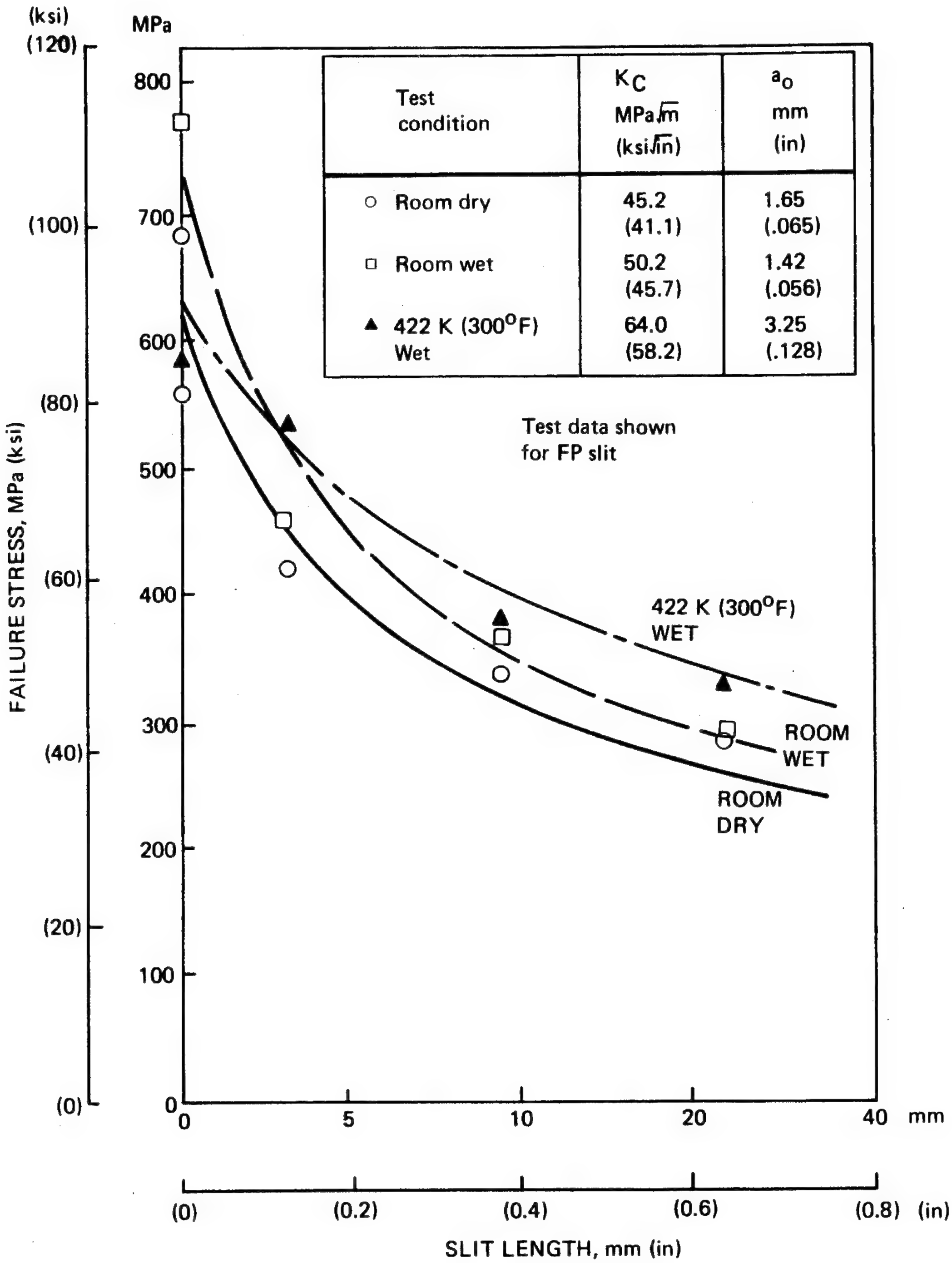
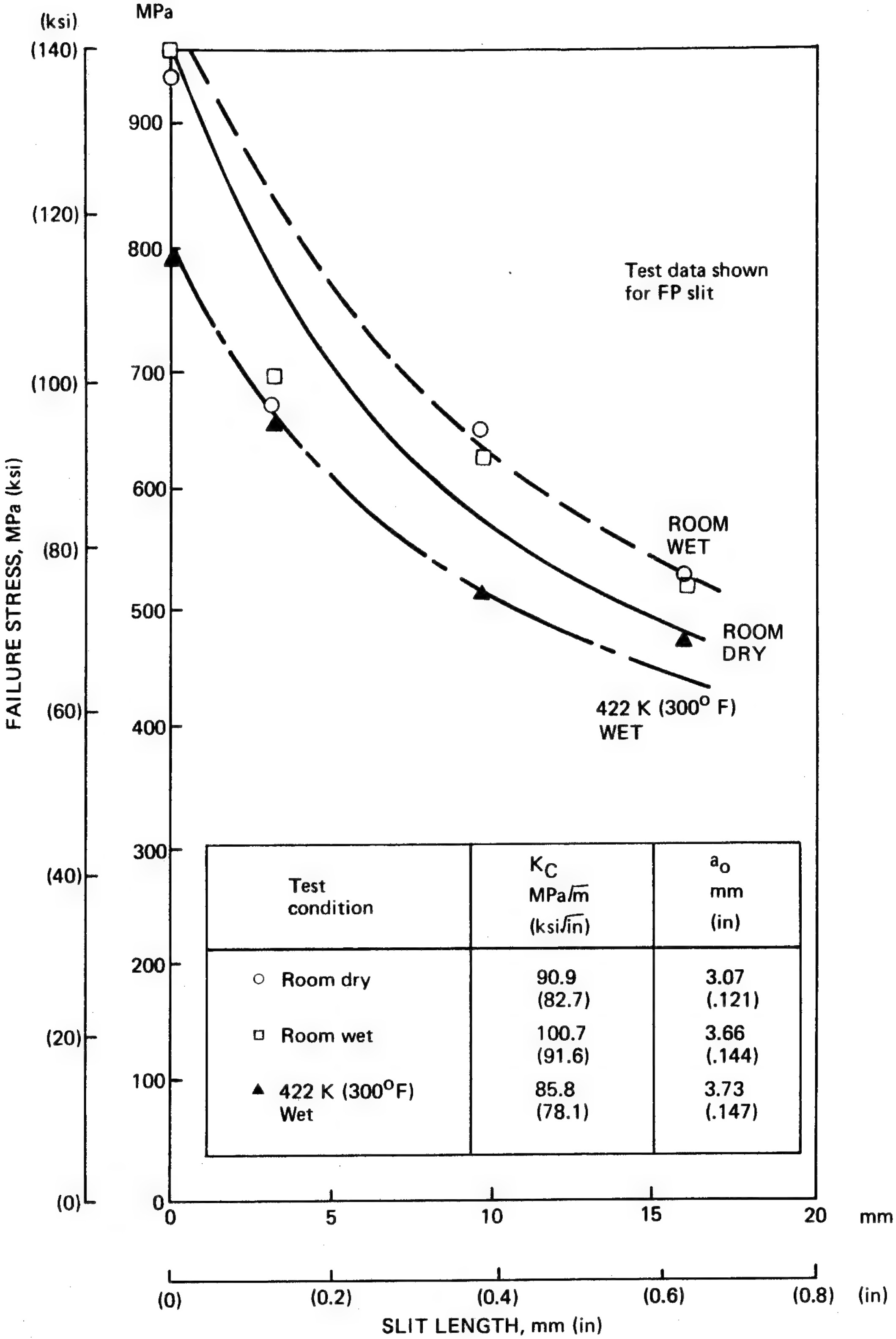


Figure 53. Comparison of Laminate L1 Fracture Data and Inherent Flaw Analysis



Test condition	K_C MPa$\sqrt{m}$ (ksi$\sqrt{in}$)	a_o mm (in)
○ Room dry	90.9 (82.7)	3.07 (.121)
□ Room wet	100.7 (91.6)	3.66 (.144)
▲ 422 K (300°F) Wet	85.8 (78.1)	3.73 (.147)

Figure 54. Comparison of Laminate L2 Fracture Data and Inherent Flaw Analysis

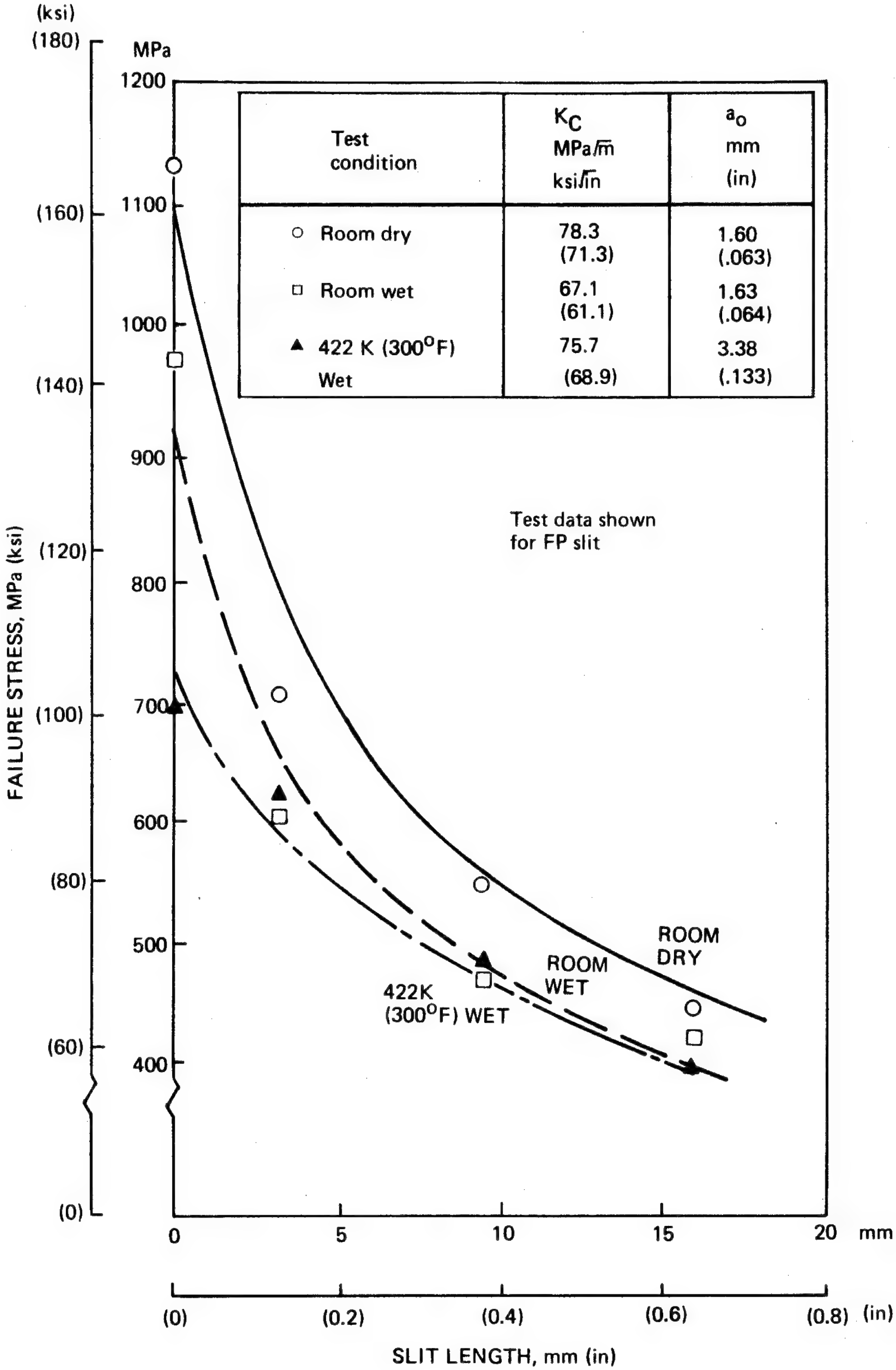
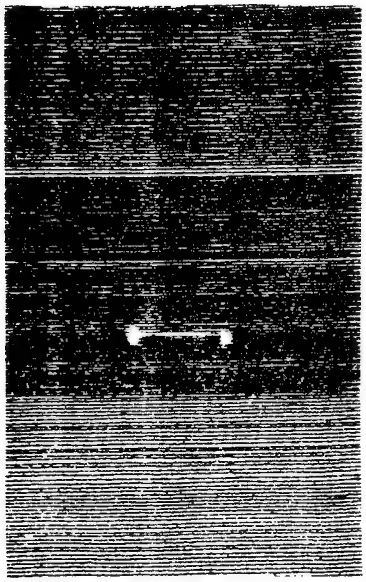
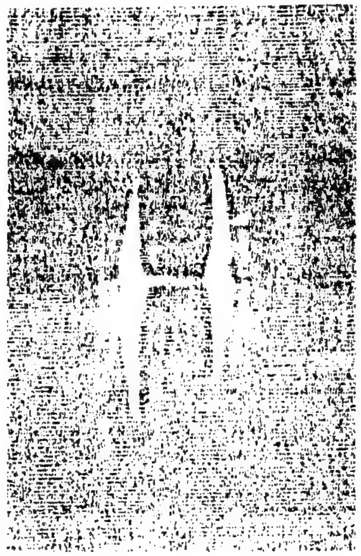


Figure 55. Comparison of Laminate L3 Fracture Data and Inherent Flaw Analysis

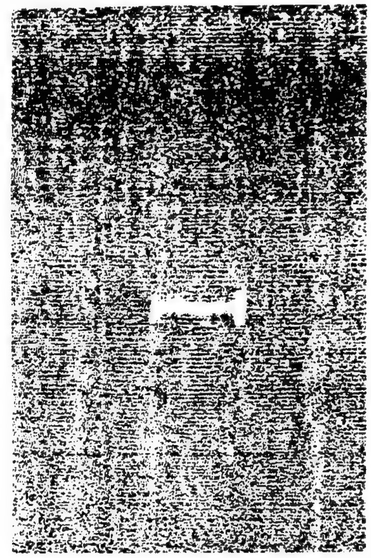
LAMINATE L1 | L2 | L3



L1-21-32



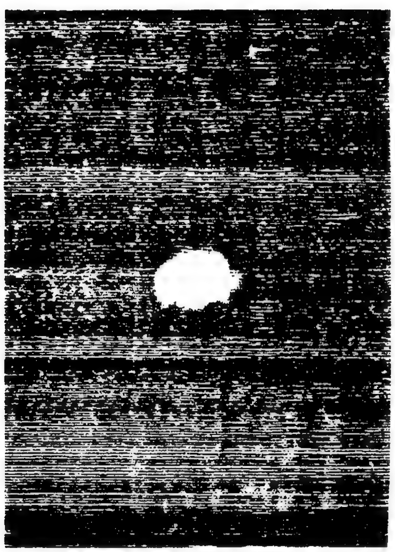
L2-21-28



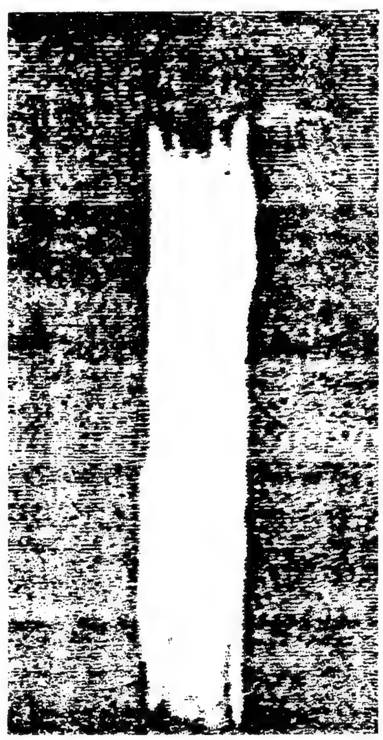
L3-21-12

5/8 FP SLIT

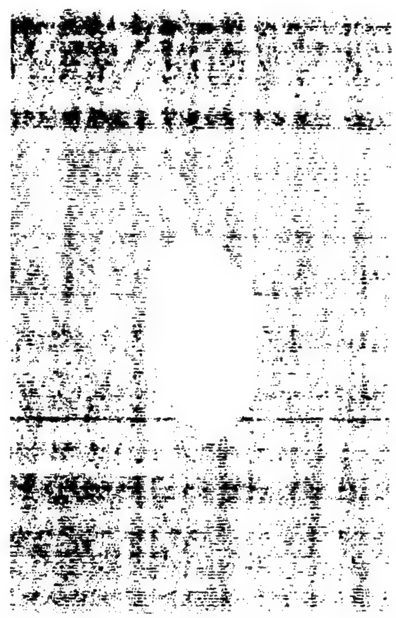
LAMINATE L1 | L2 | L3



L1-21-66



L2-21-32



L3-21-32

5/8 HP SLIT

Figure 56. Typical C-Scan Damage in Preloaded Test Specimens

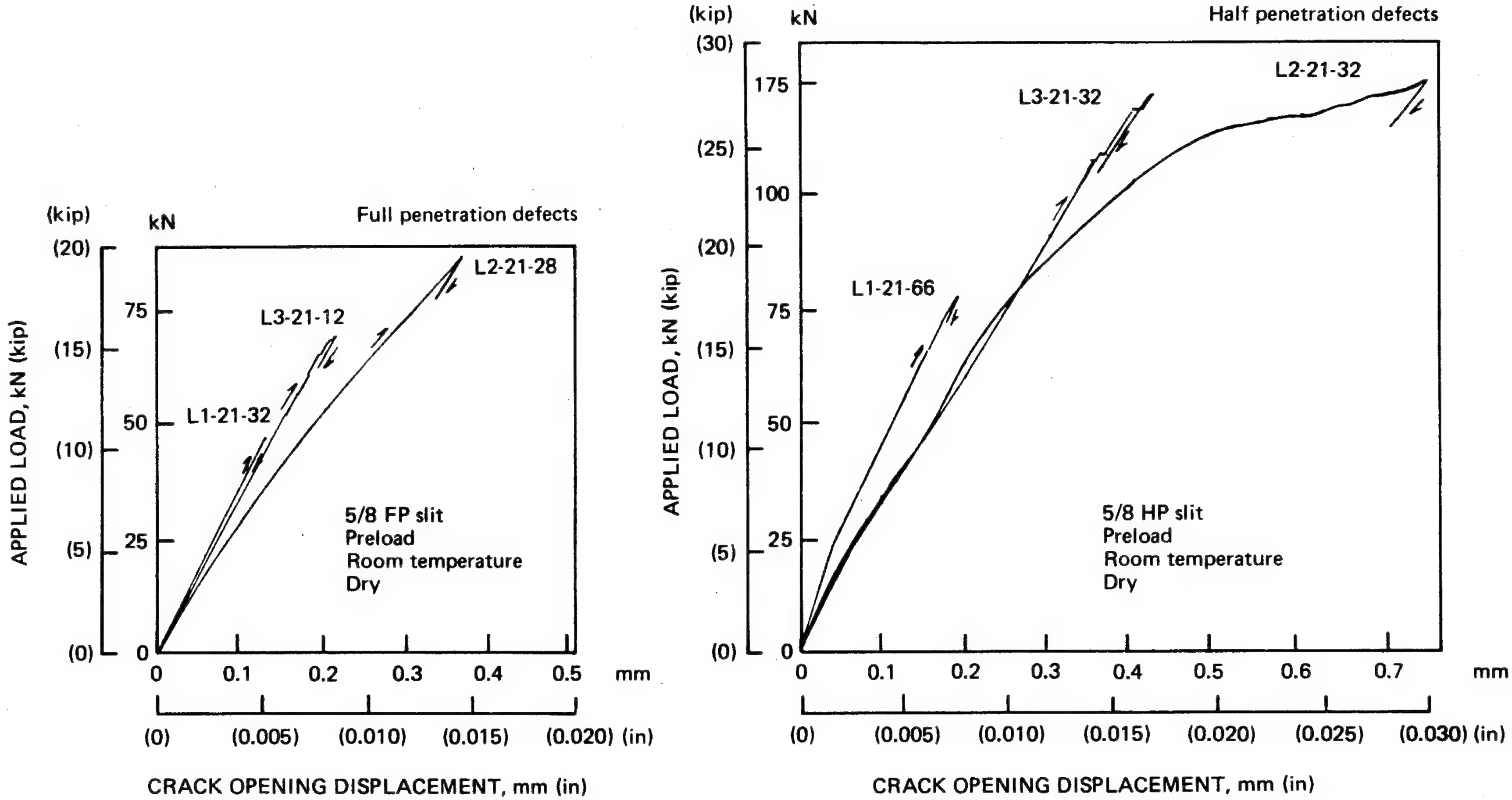


Figure 57. Typical Crack Opening Displacement Records for Preloaded Test Specimens

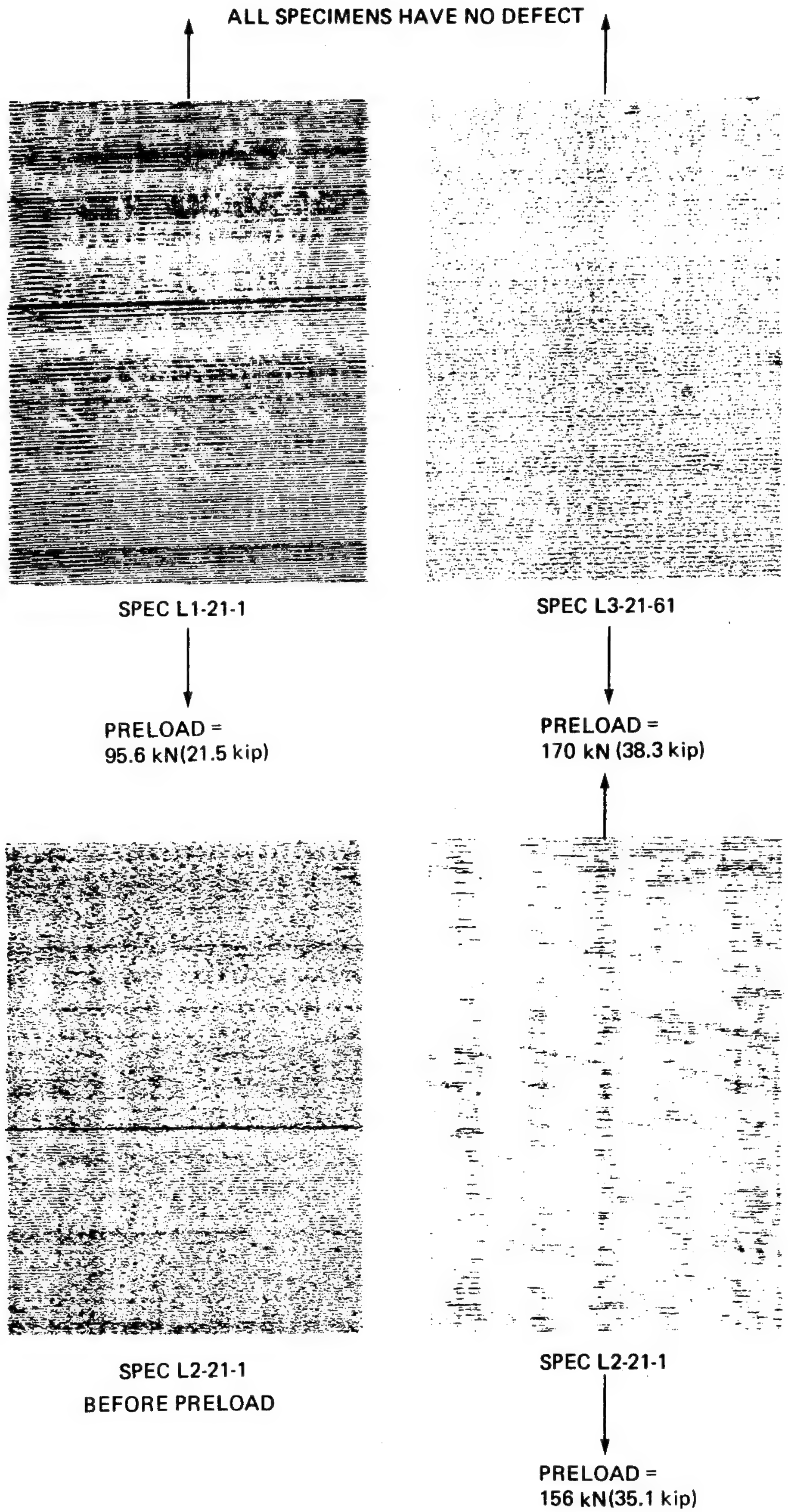
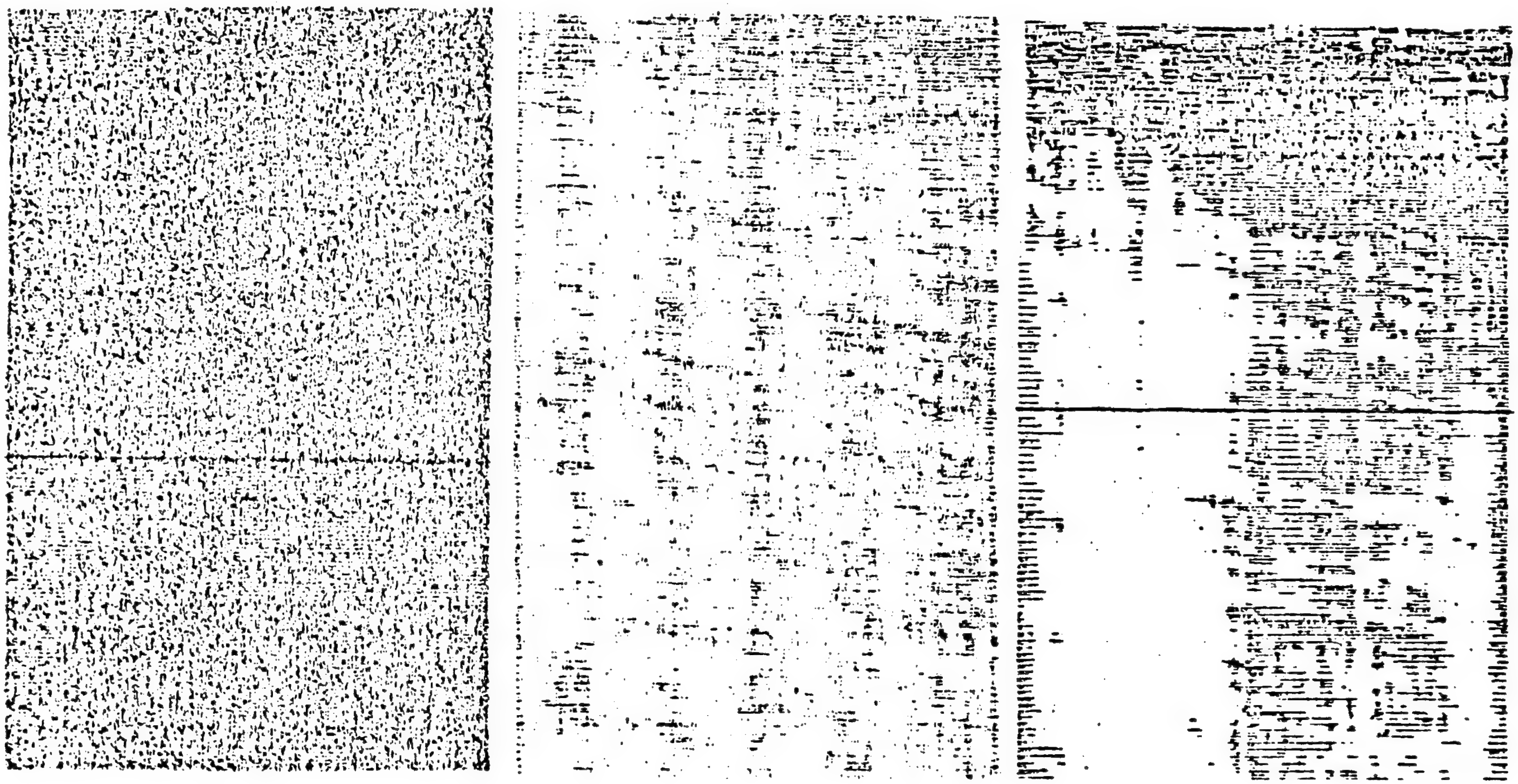


Figure 58. Effect of Preload on C-Scan Damage in Unnotched Laminates

SPEC L2-21-1



BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

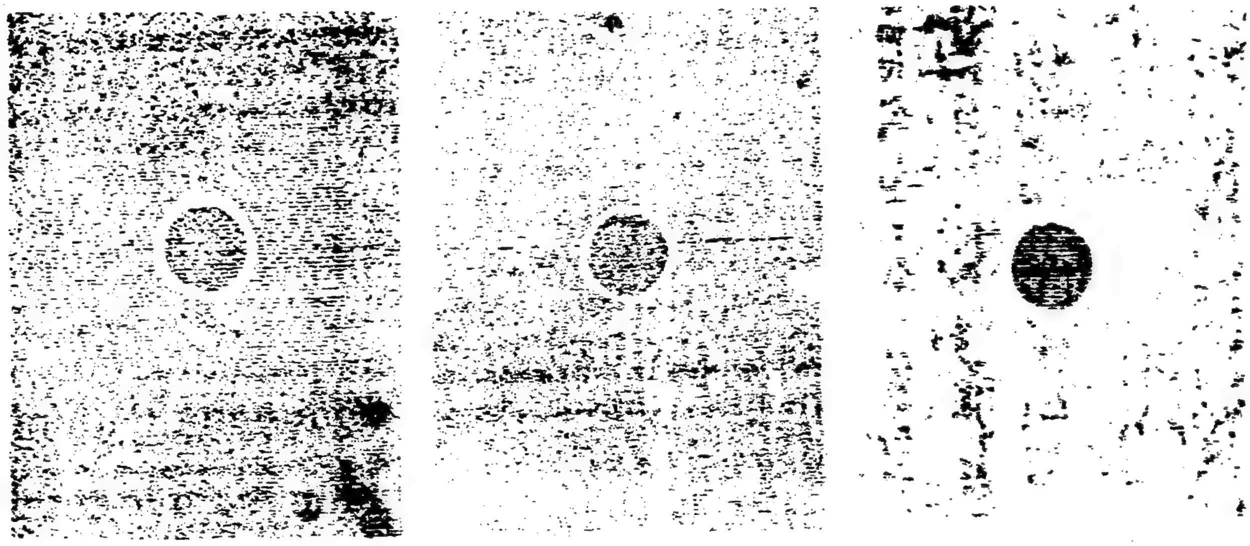
Figure 59. Ultrasonic C-Scan Records for Unnotched Laminate L2 Specimen

ALL SPECIMENS HAVE 5/8 INCH FULL PENETRATION HOLE

SPEC L2-22-1
345 kPa (50 psi) CURE

SPEC L2-23-4
172 kPa (25 psi) CURE

SPEC L2-24-1
86kPa (12.5 psi) CURE



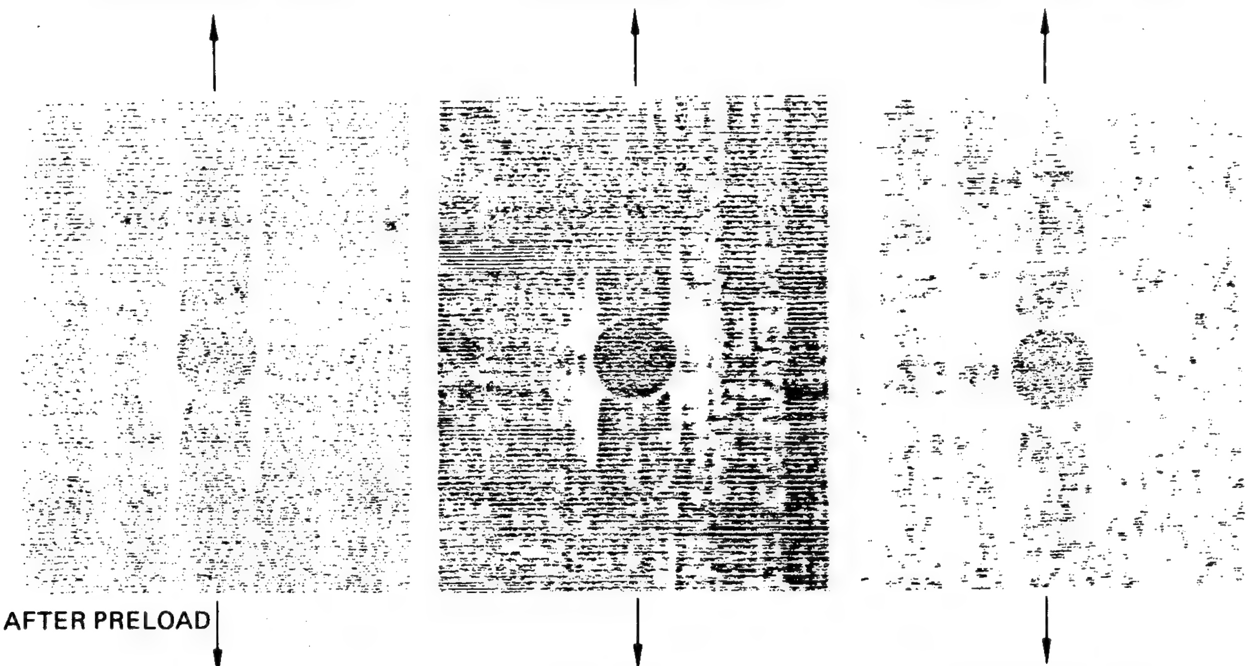
BEFORE PRELOAD

Figure 60. Effect of Autoclave Pressure on C-Scan Record

SPEC L2-22-1
345KPa (50 psi) CURE

SPEC L2-23-4
172 kPa (25 psi) CURE

SPEC L2-24-1
86kPa (12.5 psi) CURE



AFTER PRELOAD

79.2 kN (17.8 kip)

80.9 kN(18.2 kip)

89.8 kN(20.2 kip)

Figure 61. Effect of Autoclave Pressure and Preload on C-Scan Record

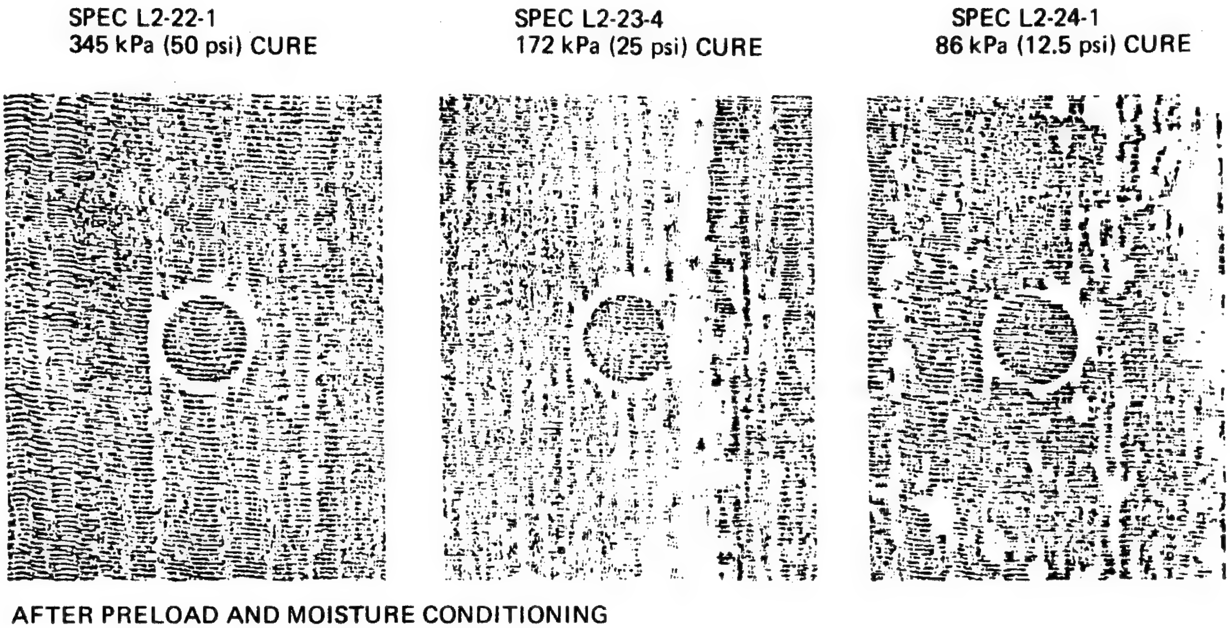


Figure 62. Effect of Autoclave Pressure, Preload and Moisture on C-Scan Record

- Test at –
  - Room temperature and 422K (300°F)
  - Wet and dry

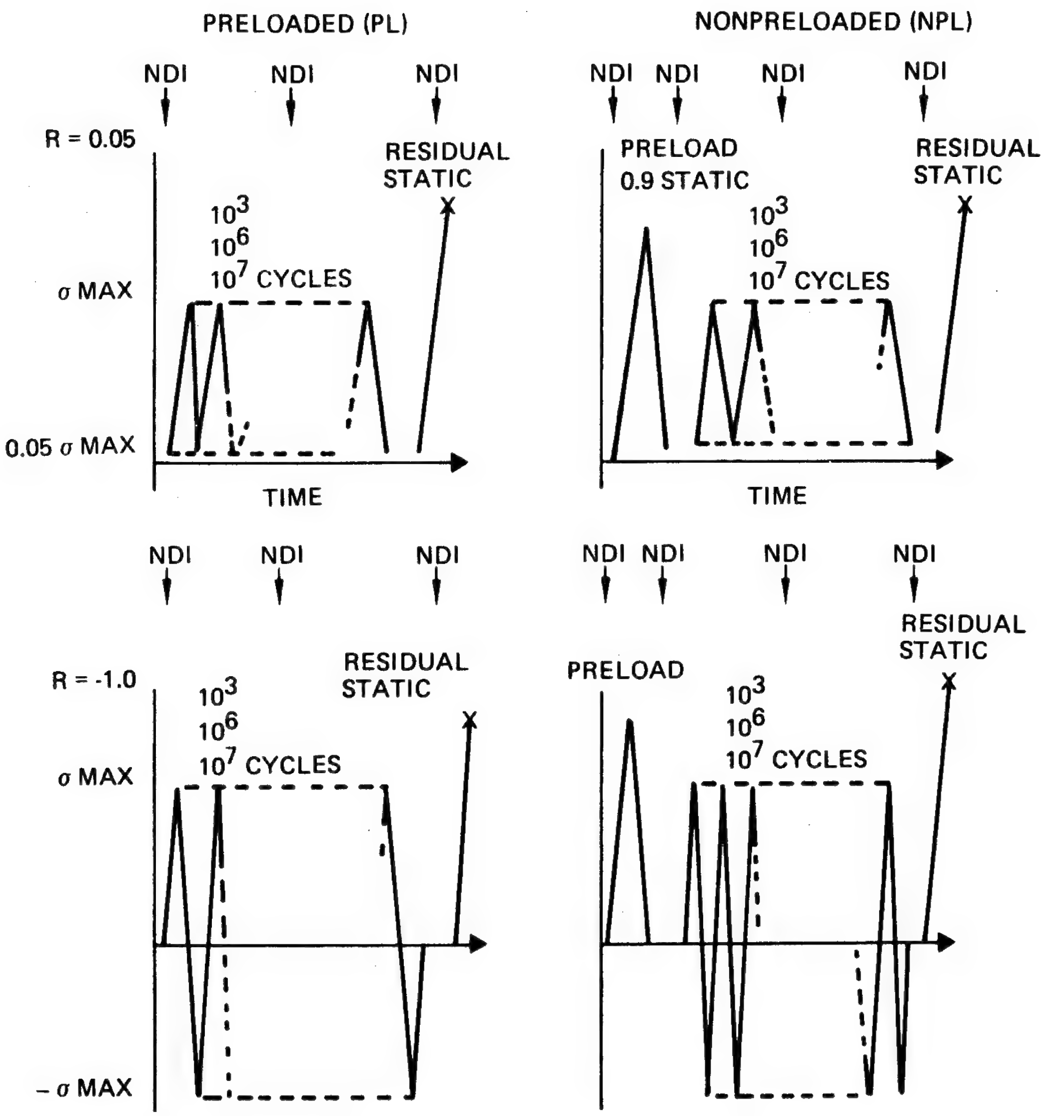


Figure 63. Environmental Cyclic Test Loading Patterns

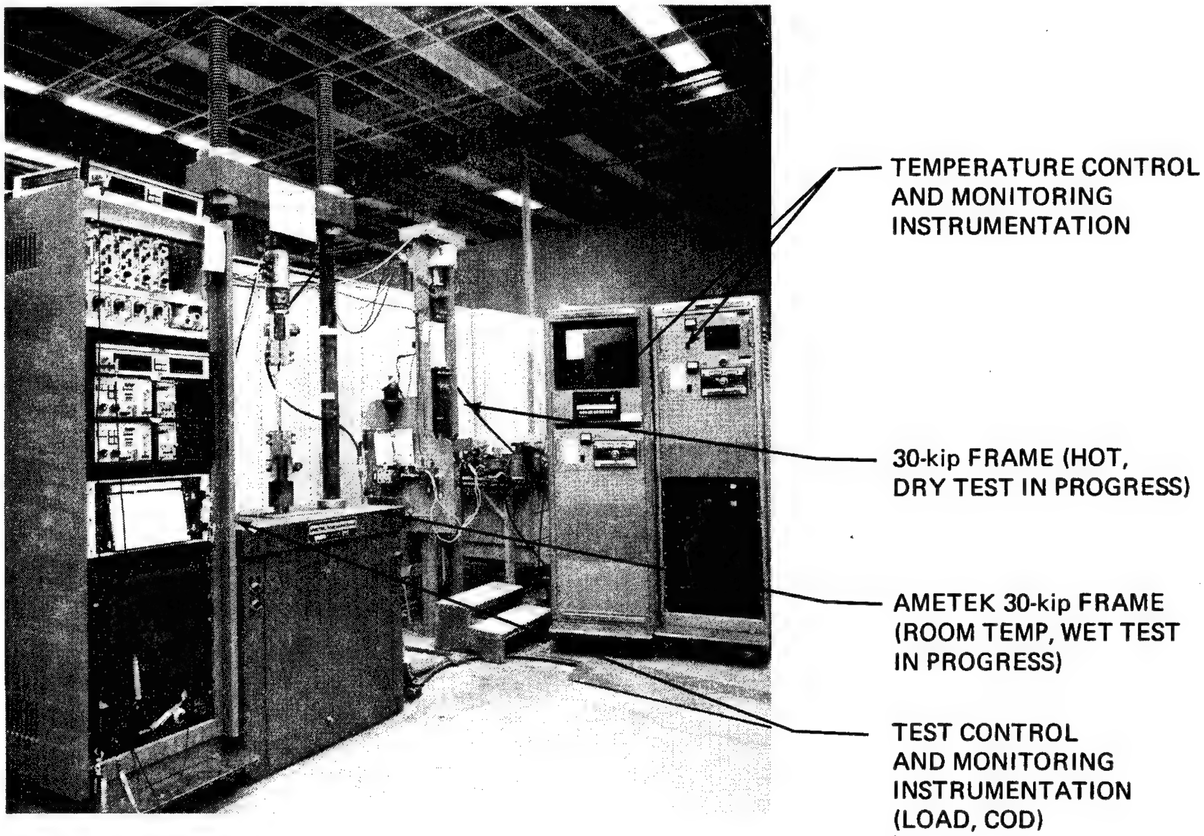


Figure 64. Environmental Cyclic Test Setup

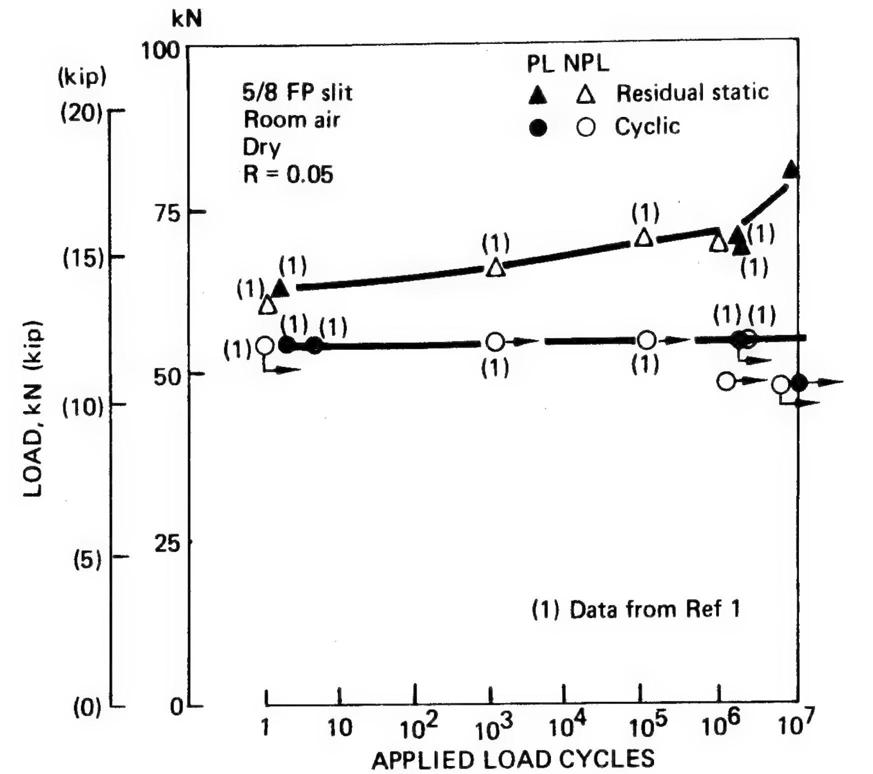


Figure 65. Room Temperature Dry Tension/Tension Tests (5/8 FP Slit)

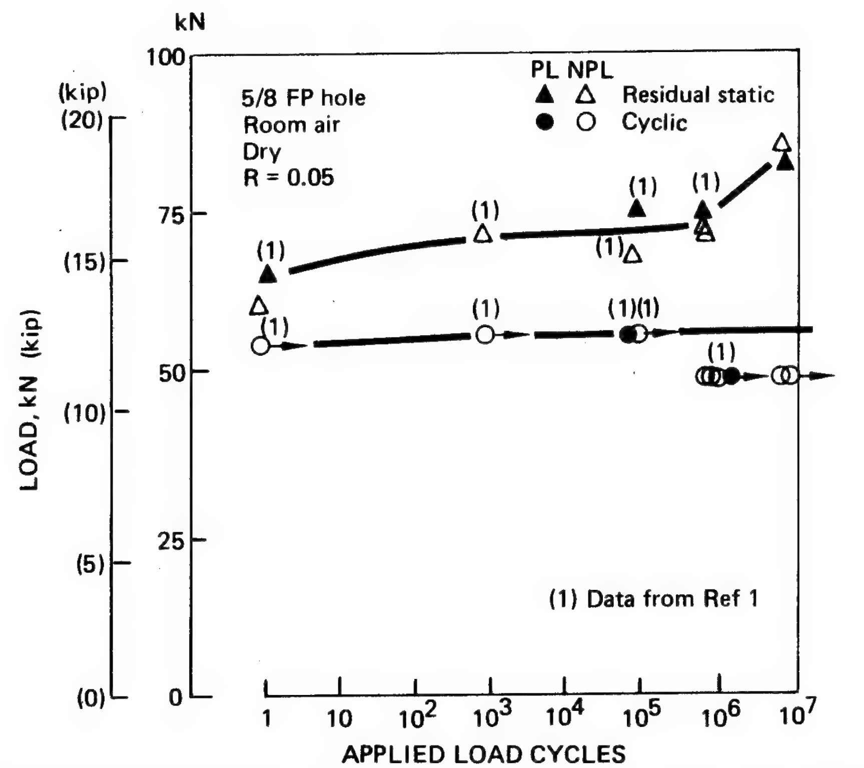


Figure 66. Room Temperature Dry Tension/Tension Tests (5/8 FP Hole)

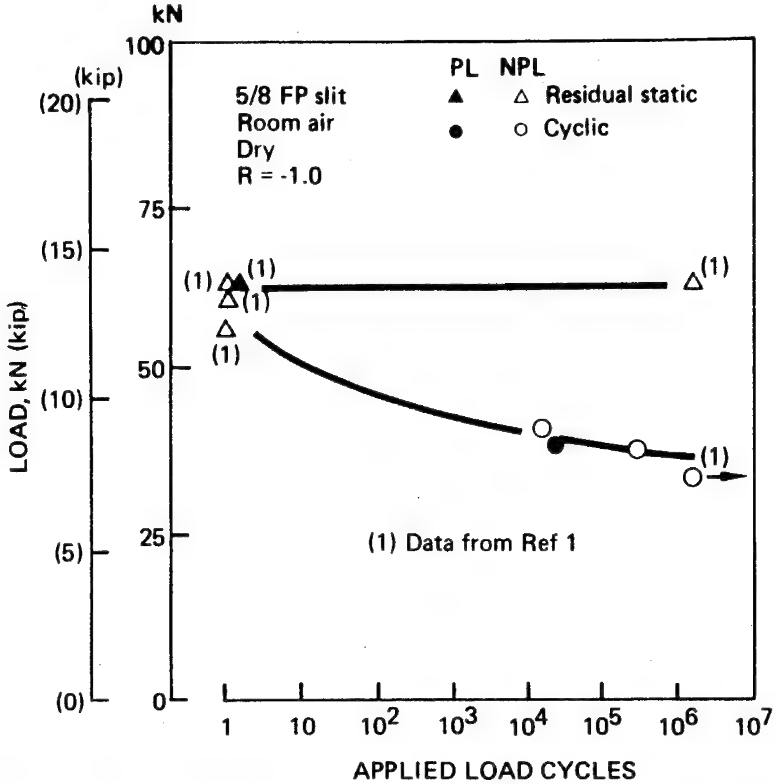


Figure 67. Room Temperature Dry Tension/Compression Tests (5/8 FP Slit)

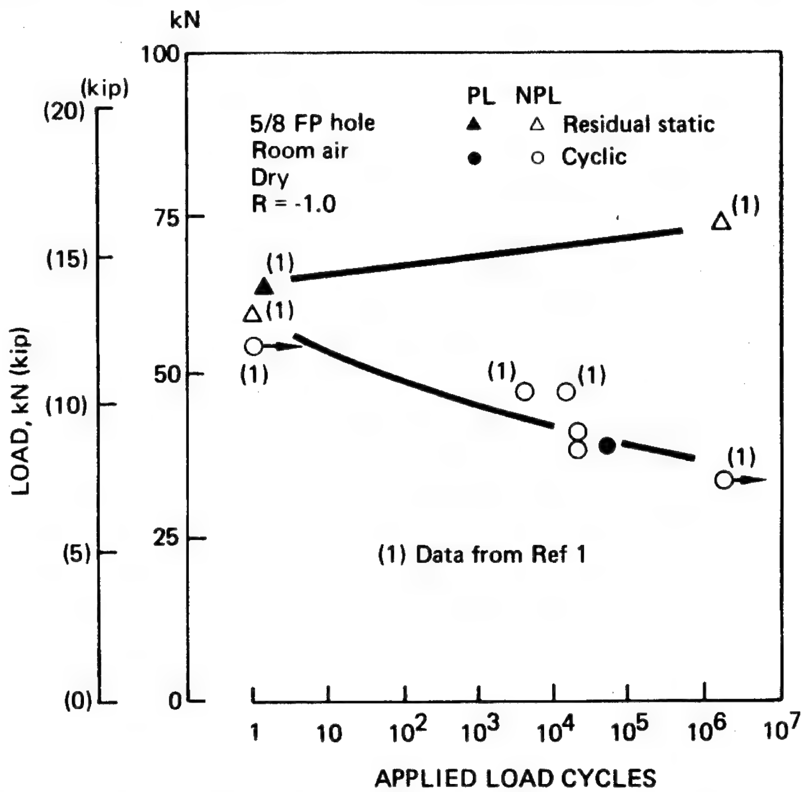


Figure 68. Room Temperature Dry Tension/Compression Tests (5/8 FP Hole)

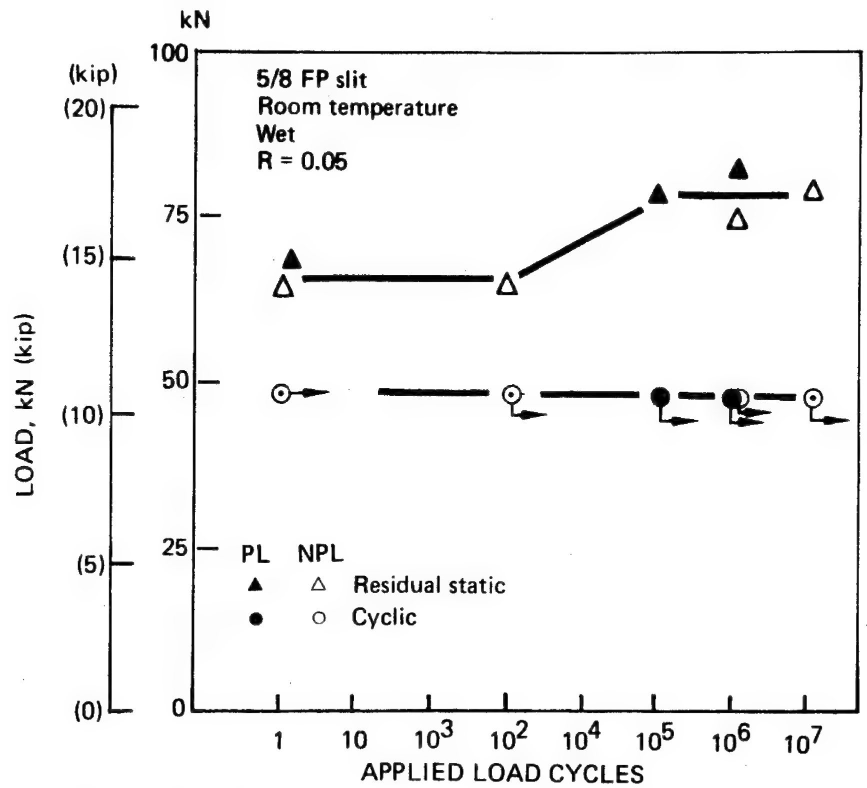


Figure 69. Room Temperature Wet Tension/Tension Tests (5/8 FP Slit)

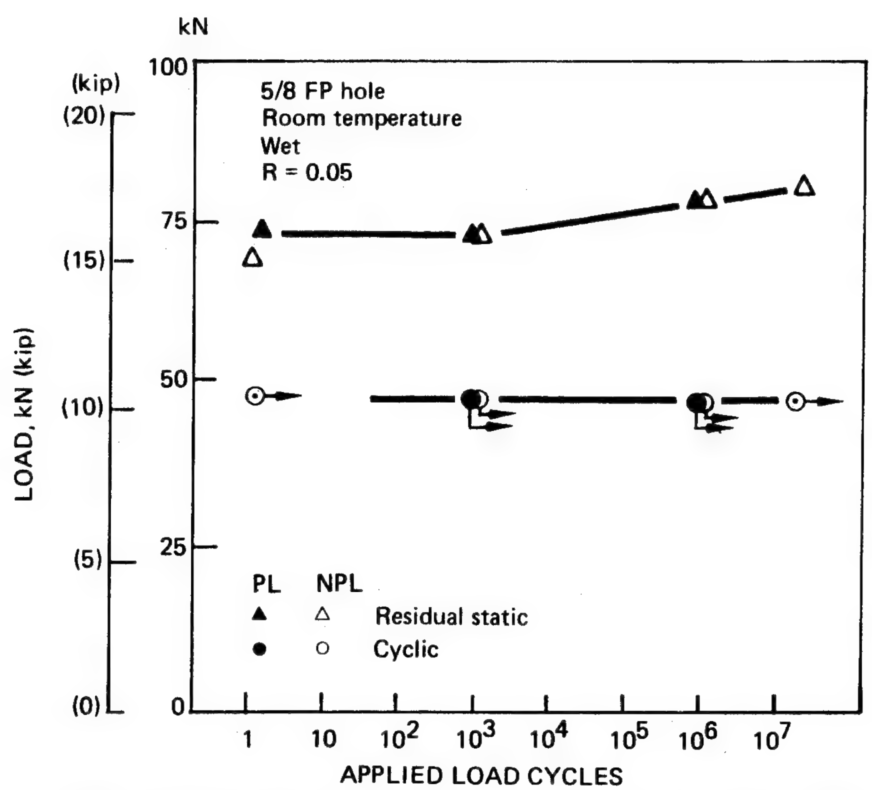


Figure 70. Room Temperature Wet Tension/Tension Tests (5/8 FP Hole)

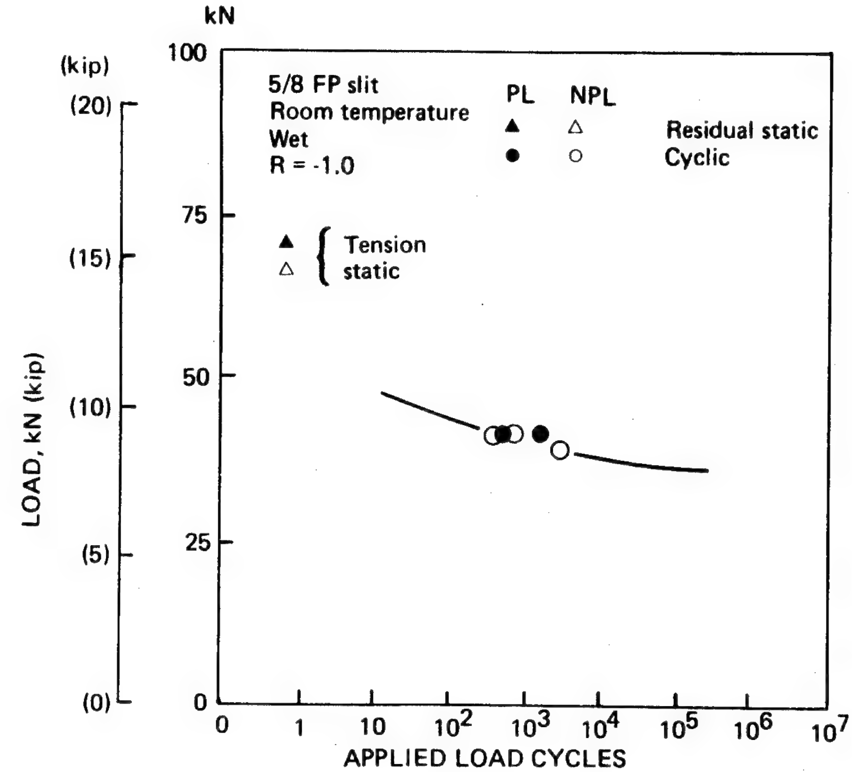


Figure 71. Room Temperature Wet Tension/Compression Tests (5/8 FP Slit)

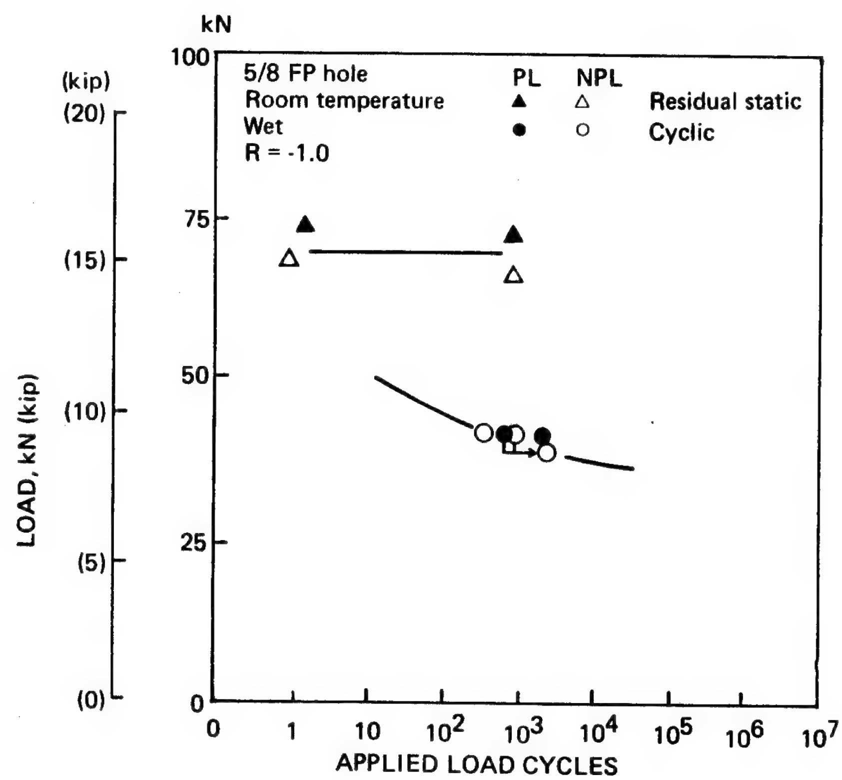


Figure 72. Room Temperature Wet Tension/Compression Tests (5/8 FP Hole)

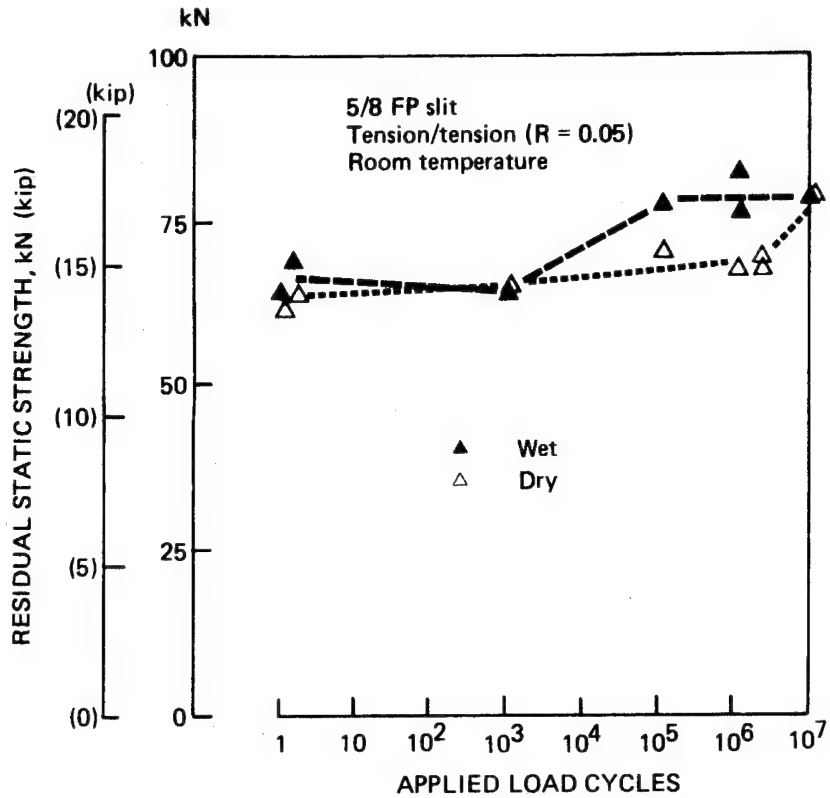


Figure 73. Influence of Moisture on Residual Static Strength for Slit Specimens

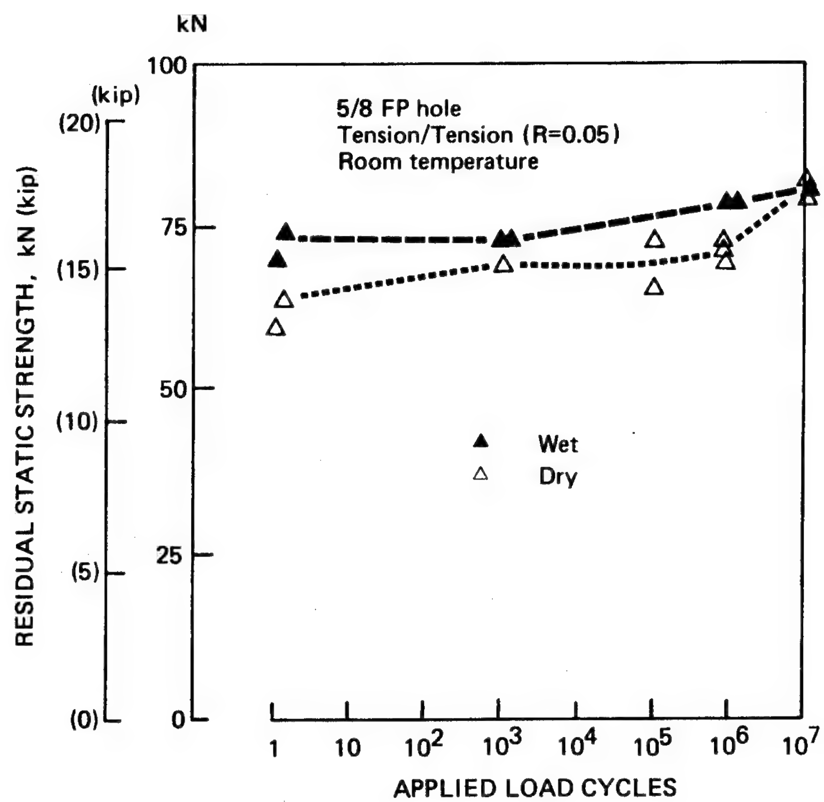


Figure 74. Influence of Moisture or Residual Static Strength for Hole Specimens

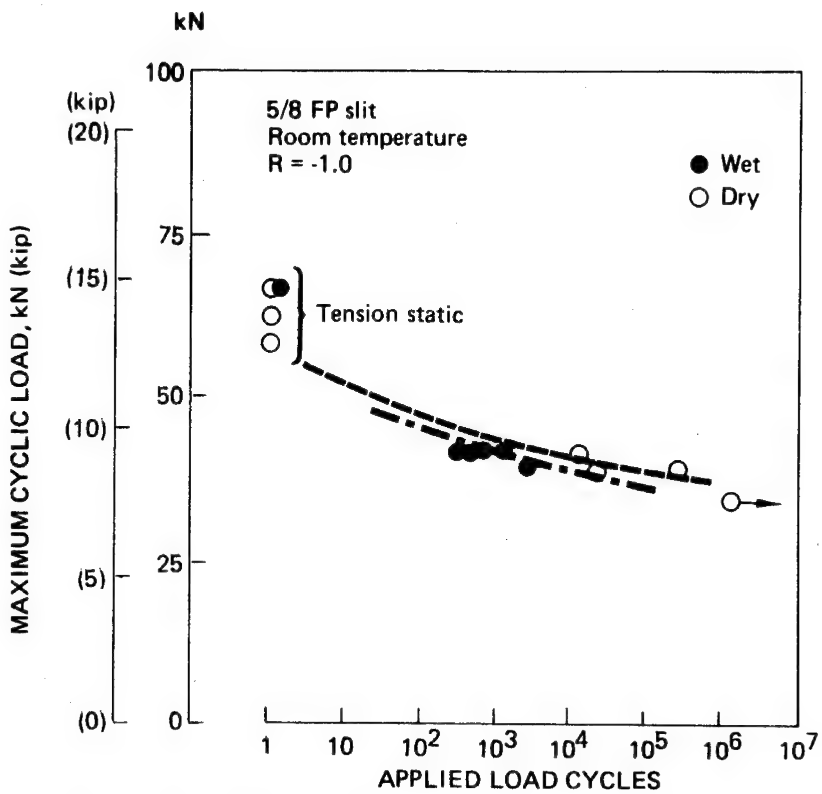


Figure 75. Influence of Moisture on Tension/Compression Fatigue for Slit Specimens

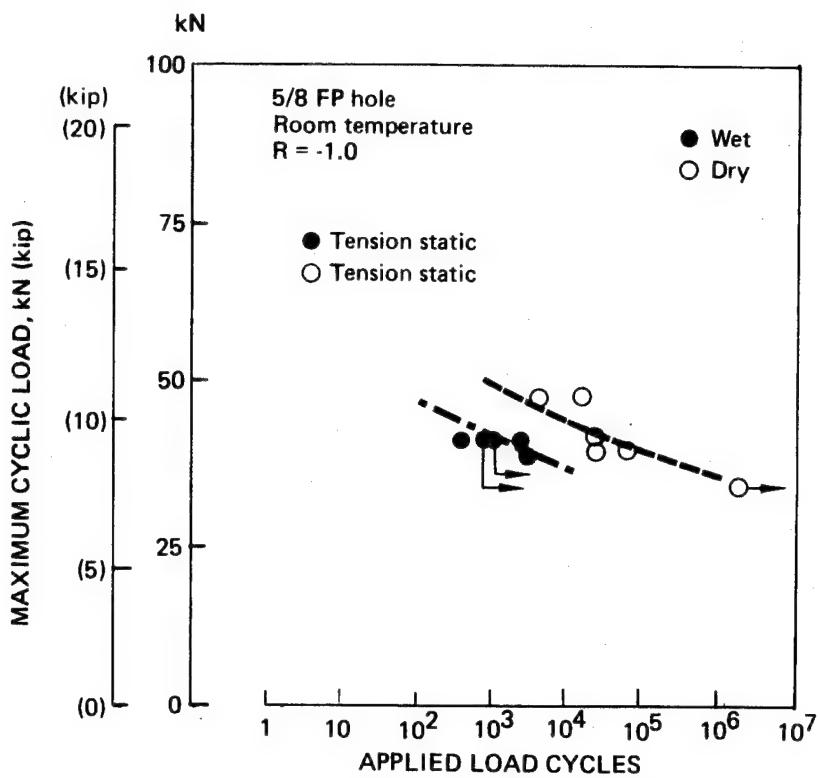


Figure 76. Influence of Moisture on Tension/Compression Fatigue for Hole Specimens

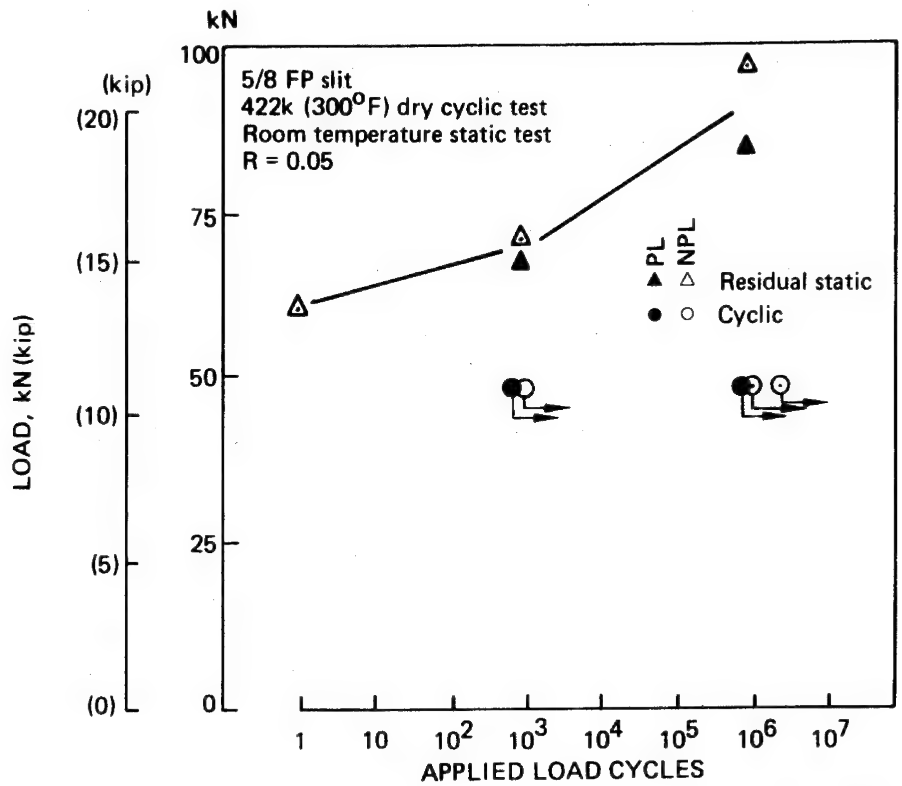


Figure 77. Elevated Temperature Dry Tension/Tension Tests (5/8 FP Slit)

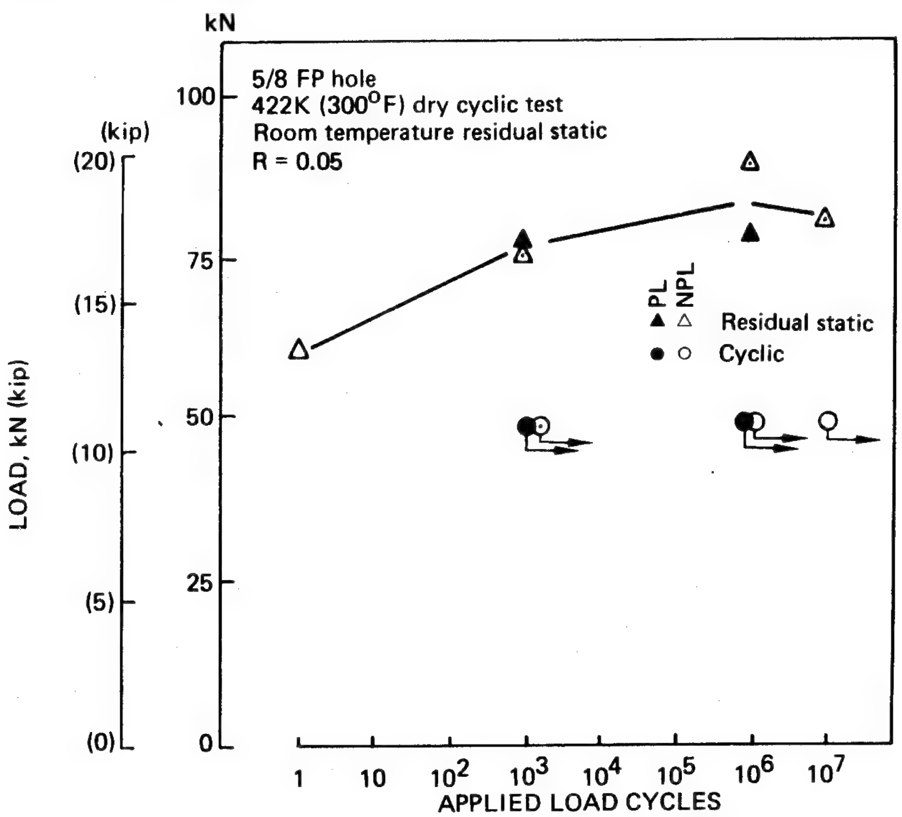


Figure 78. Elevated Temperature Dry Tension/Tension Tests (5/8 FP Hole)

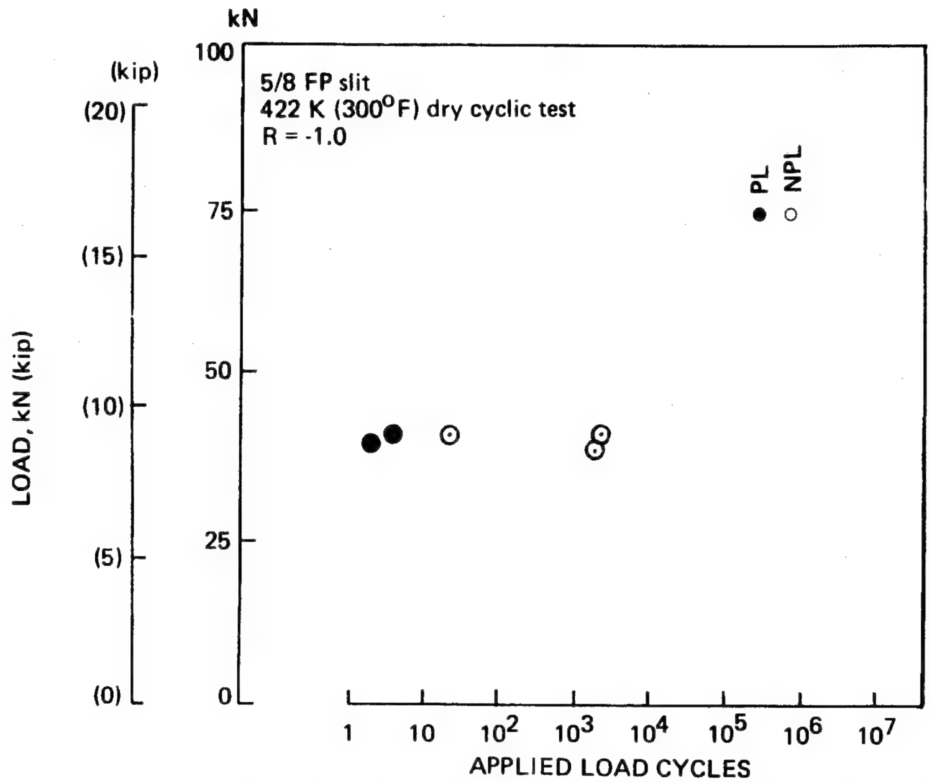


Figure 79. Elevated Temperature Dry Tension/Compression Tests (5/8 FP Slit)

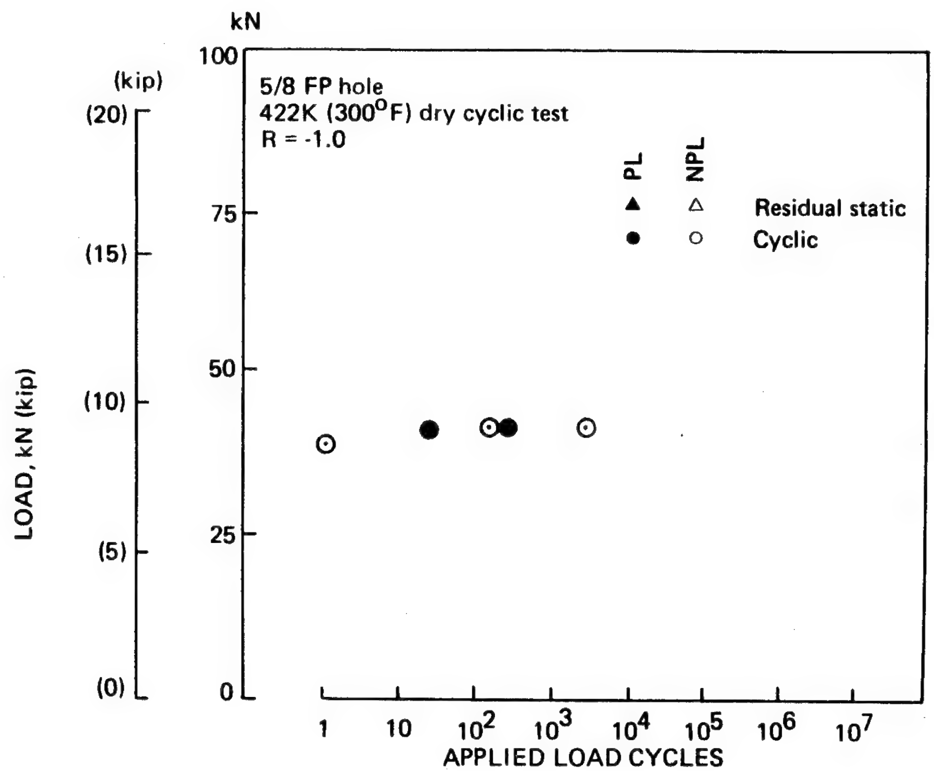


Figure 80. Elevated Temperature Dry Tension/Compression Tests (5/8 FP Hole)

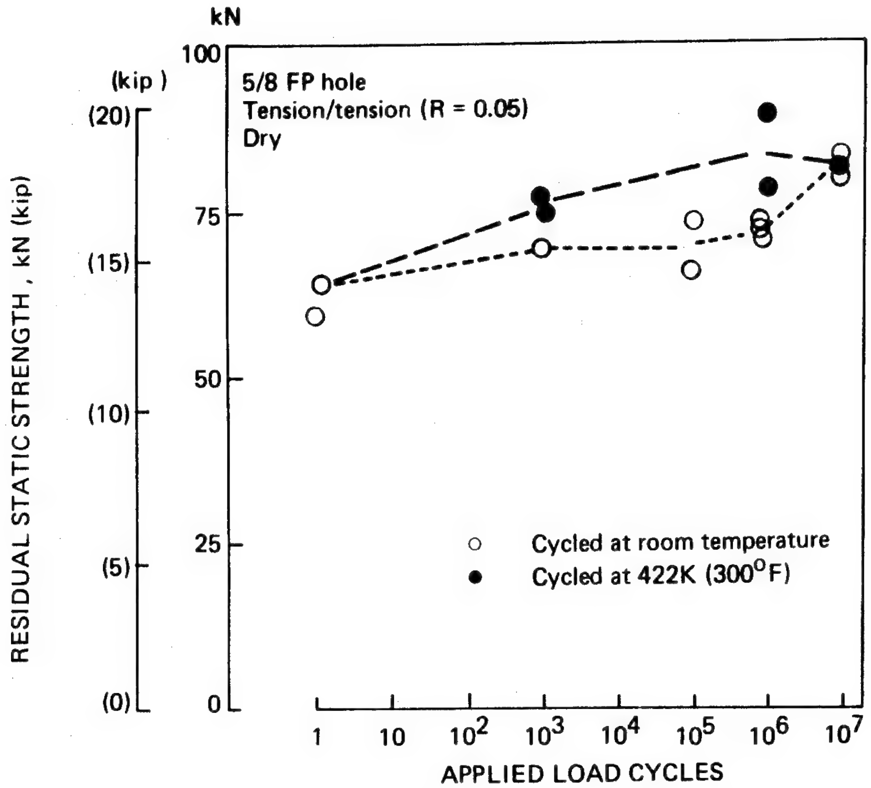


Figure 81. Influence of Cycling Temperature on Residual Strength of Dry Slit Specimens

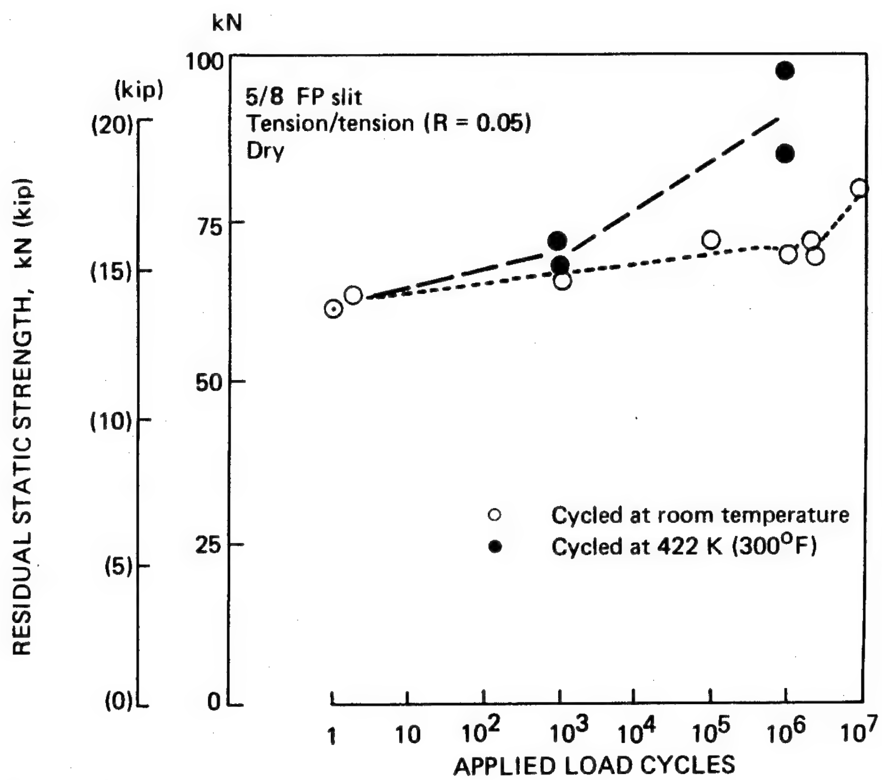


Figure 82. Influence of Cycling Temperature on Residual Strength of Dry Hole Specimens

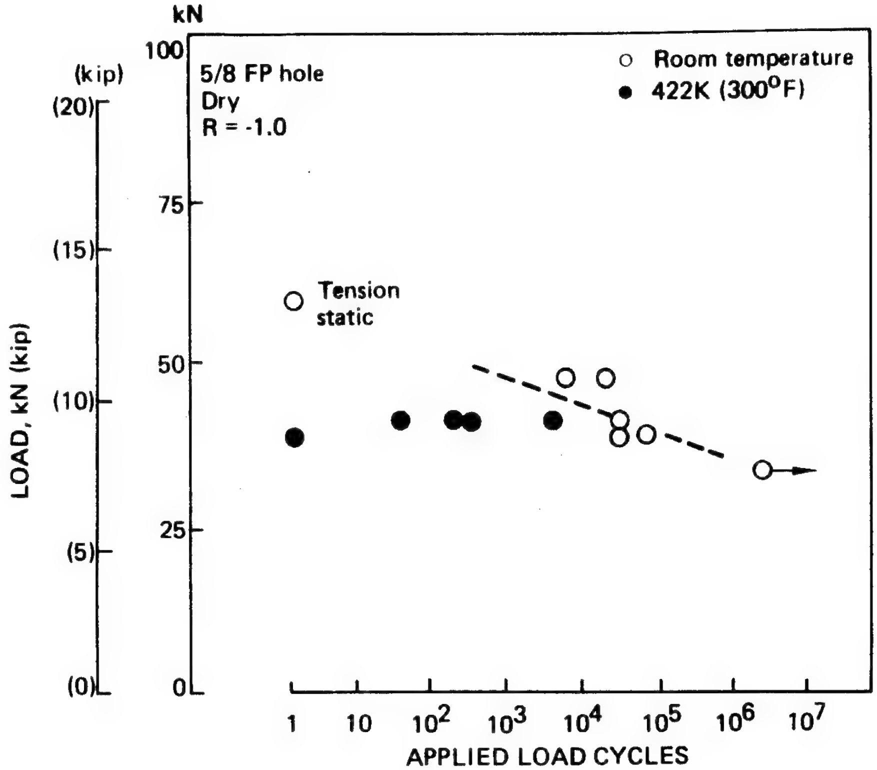


Figure 83. Influence of Cycling Temperature on Fatigue Strength of Dry Slit Specimens

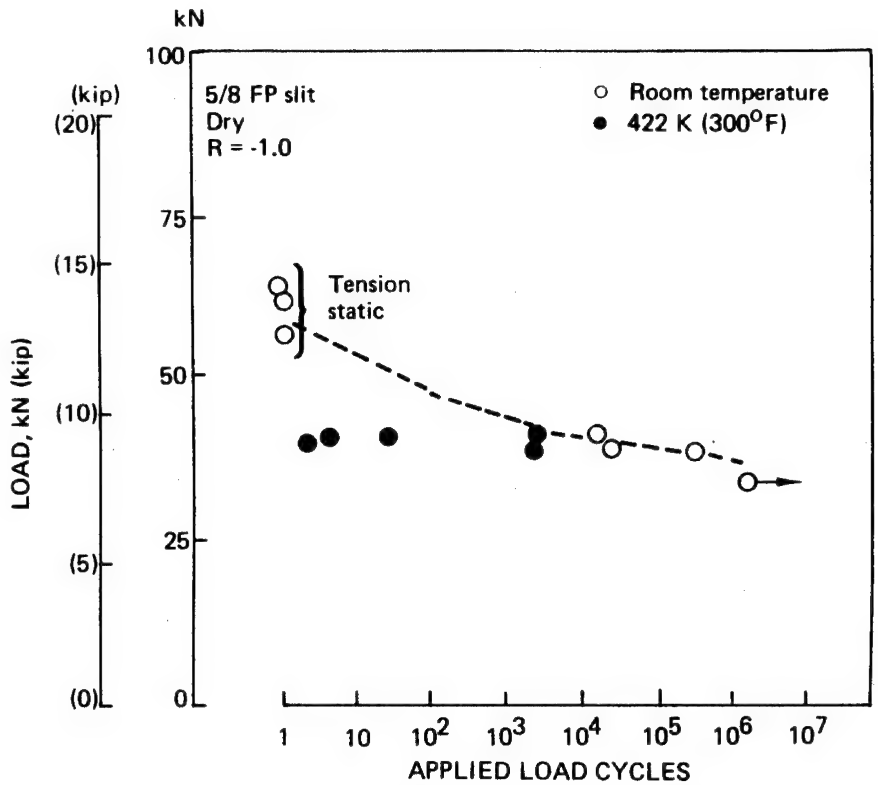


Figure 84. Influence of Cycling Temperature on Fatigue Strength of Dry Hole Specimens

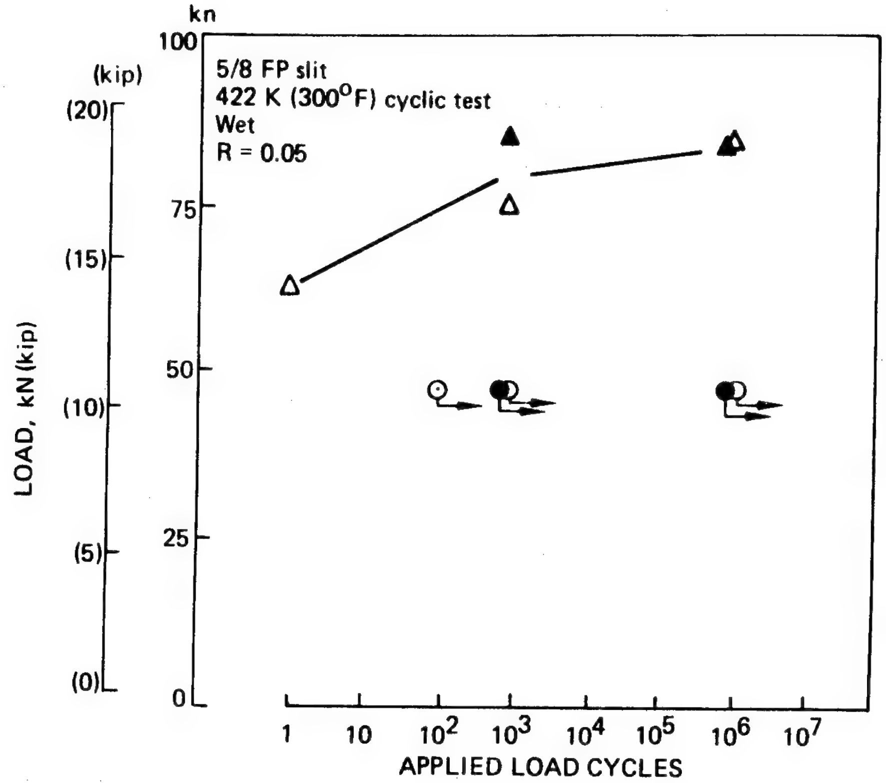


Figure 85. Elevated Temperature Wet Tension/Tension Tests (5/8 FP Slit)

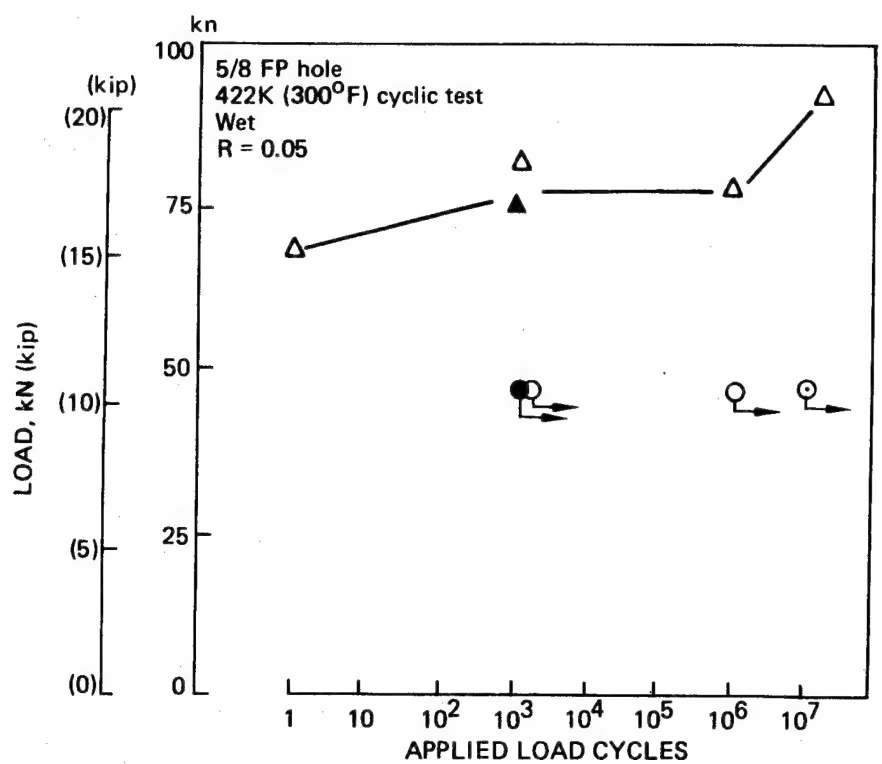


Figure 86. Elevated Temperature Wet Tension/Tension Tests (5/8 FP Hole)

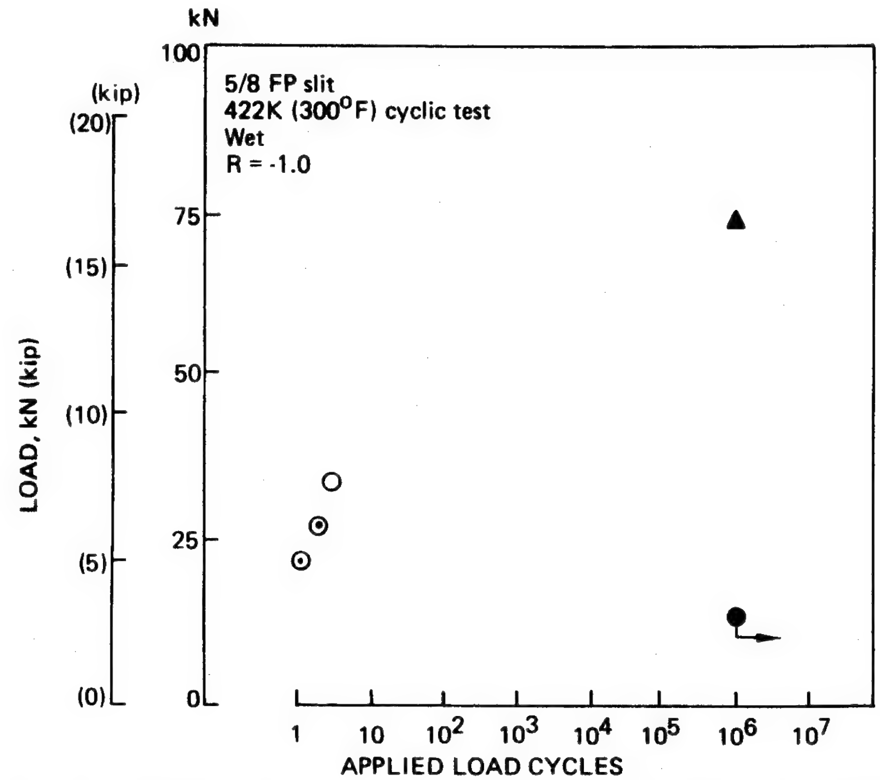


Figure 87. Elevated Temperature Wet Tension/Compression Tests (5/8 FP Slit

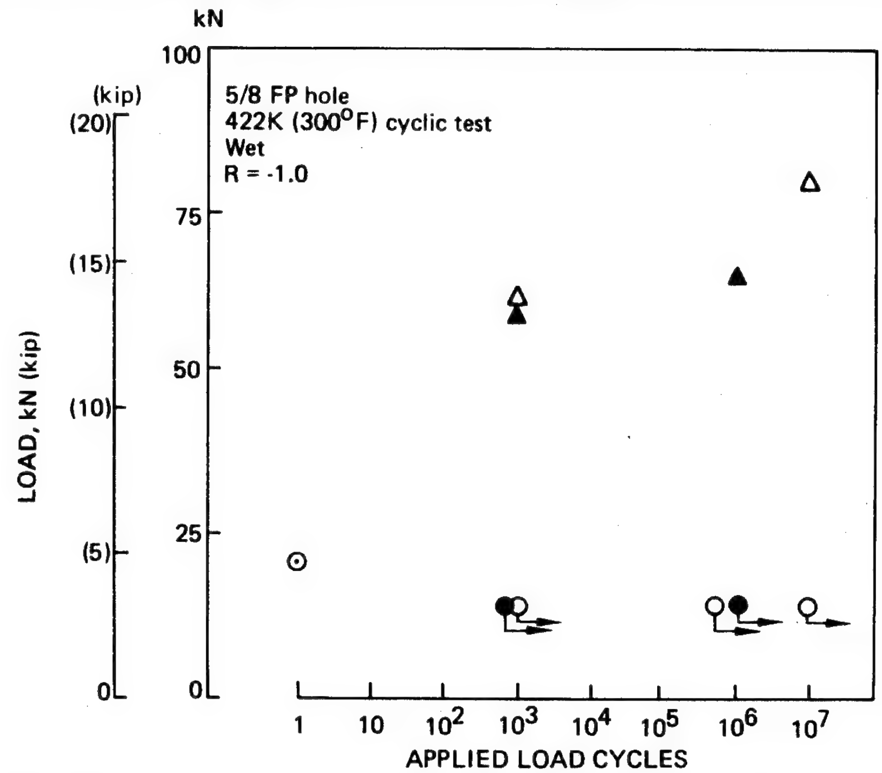


Figure 88. Elevated Temperature Wet Tension/Compression Tests (5/8 FP Hole

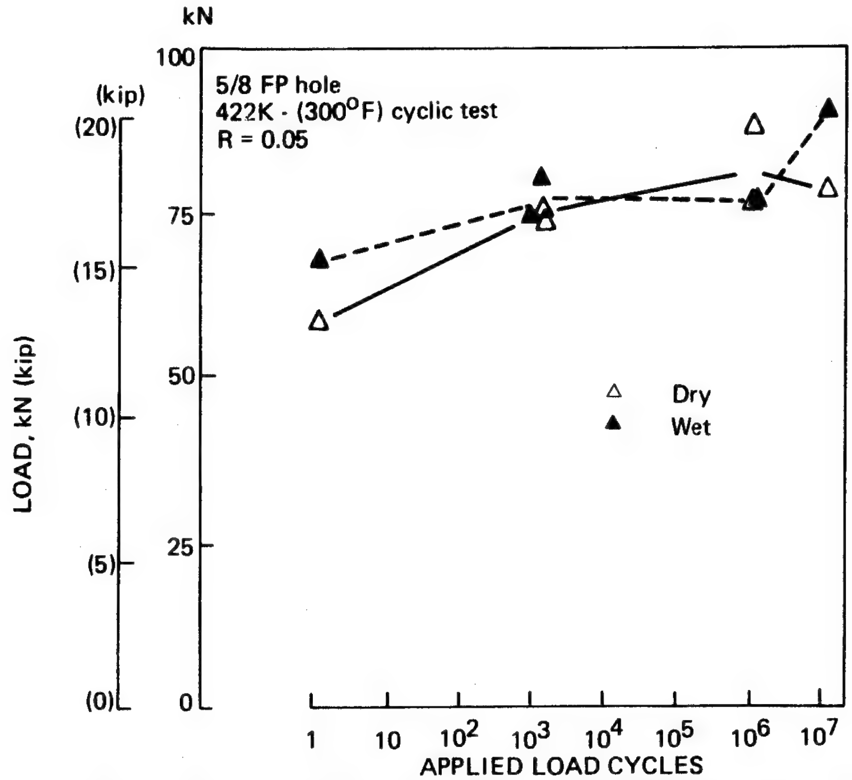


Figure 89. Influence of Moisture Content, on Residual Strength of Hole Specimens Cycled at Elevated Temperature

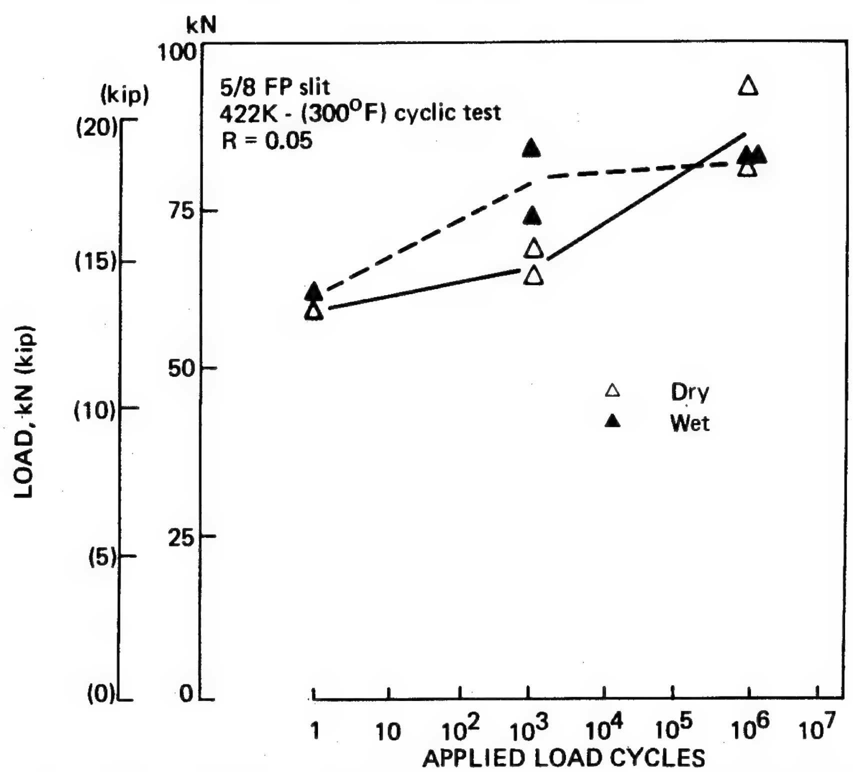


Figure 90. Influence of Moisture Content, on Residual Strength of Slit Specimens Cycled at Elevated Temperature

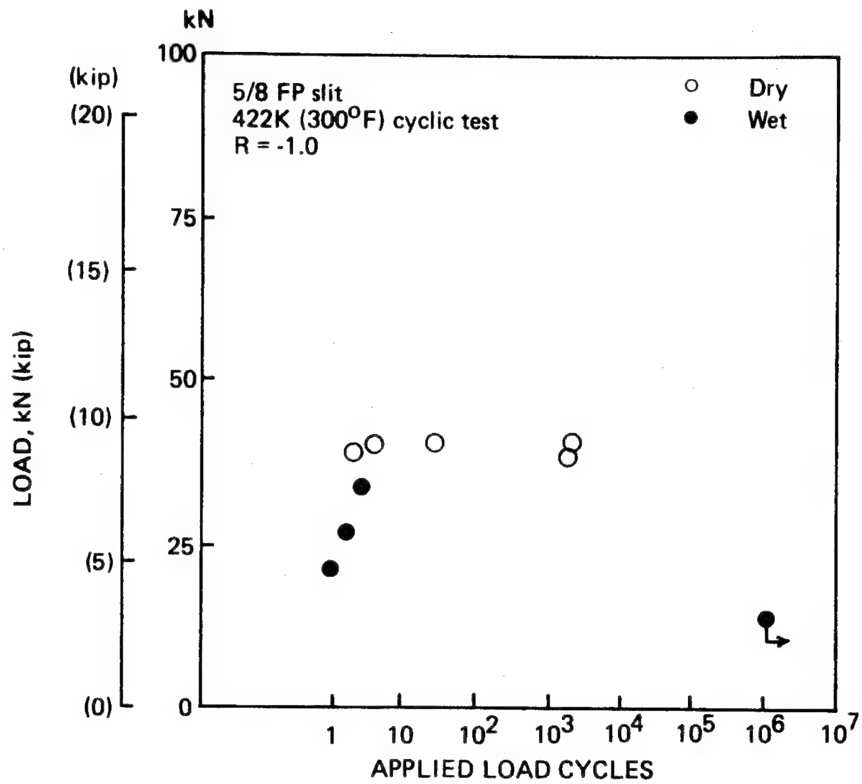


Figure 91. Influence of Moisture Content on Elevated Temperature Fatigue of Slit Specimens

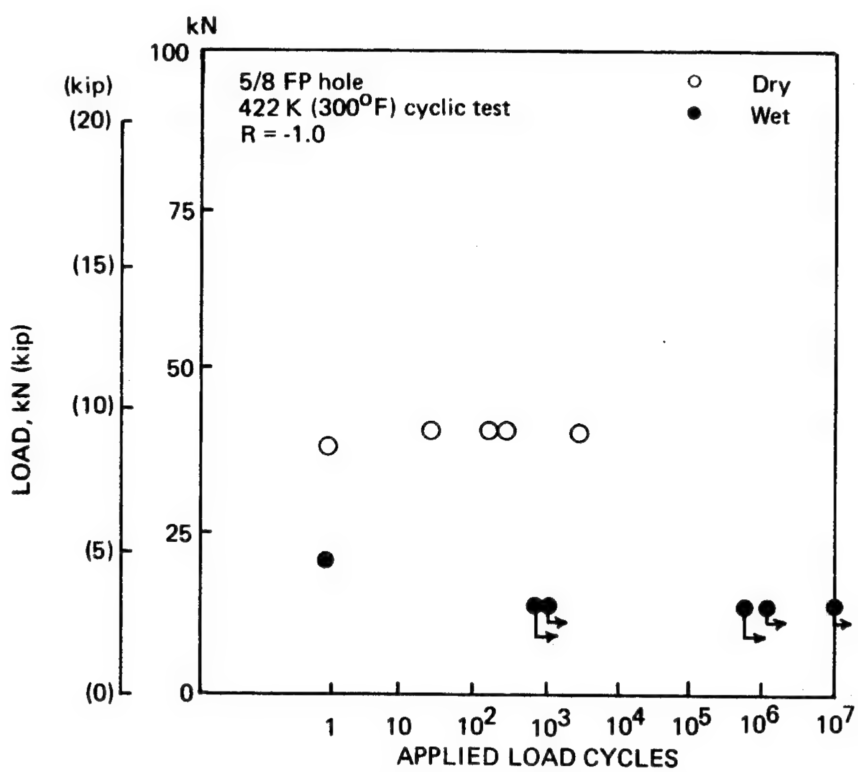


Figure 92. Influence of Moisture Content on Elevated Temperature Fatigue of Hole Specimens

REFERENCES

1. Porter, T.R.: Evaluation of Flawed Composite Structural Components Under Static and Cyctic Loading, NASA CR-135403, prepared under Boeing Contract NAS3-19709 with NASA-Lewis Research Center, February 1979.

2. Waddoups, M.E., Eisenmann, J.R., and Kamminski, B.E.: Microscopic Fracture Mechanics of Advanced Composite Materials, Journal of Composite Materials, vol. 5, October 1971.

APPENDIX A

STATIC AND CYCLIC TEST DATA

This appendix contains the static and cyclic test data for all specimens. The reported data includes specimen geometry, loads, and test parameters. The gross section stresses have been reported for all the critical test conditions.

WIDTH EFFECT TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-31A -1	L1 [1]	2.67 (.103)	47.5 (1.869)	5/8 FP SLIT	15.9 (.627)	15.6 (.613)	THRU	TENSION STATIC	ROOM	–	–	–	–	–	–	30870 (6940)	243 (35.1)	
-5		2.69 (.106)	98.6 (3.881)		15.9 (.627)	15.9 (.628)				–	–	–	–	–	–	74,700 (16,800)	281 (40.8)	
-9		2.71 (.1070)	149.4 (5.881)		15.9 (.628)	16.0 (.631)				–	–	–	–	–	–	121000 (27300)	298 (43.4)	
-2	L1	2.77 (.109)	47.4 (1.868)	5/8 FP SLIT	16.2 (.638)	15.9 (.628)	THRU	COMPRESSION STATIC	ROOM	–	–	–	–	–	–	-33000 (-7422)	-251 (-36.6)	
-6		2.74 (.108)	98.6 (3.883)		16.0 (.631)	15.8 (.623)				–	–	–	–	–	–	-44590 (-10025)	-164 (-23.9)	
-10		2.74 (.108)	149.4 (5.880)		16.0 (.630)	16.1 (.632)				–	–	–	–	–	–	-103400 (-23260)	-252 (-36.6)	
-3	L1	2.77 (.109)	49.8 (1.926)	IMPACT				TENSION STATIC	ROOM	–	–	–	–	–	–	80000 (18000)	590 (85.7)	
-7		2.72 (.107)	100.3 (3.951)							–	–	–	–	–	–	149900 (33700)	549 (79.7)	
-11		2.54 (.100)	149.3 (5.879)							–	–	–	–	–	–	143000 (32200)	377 (54.8)	GRIP AREA FAILURE
-4	L1	2.77 (.109)	48.9 (1.926)	IMPACT				COMPRESSION STATIC	ROOM	–	–	–	–	–	–	-28400 (-6390)	-209 (-30.4)	
-8		2.77 (.109)	100.4 (3.953)							–	–	–	–	–	–	-74600 (-16775)	-268 (-39.0)	
-12		2.69 (.106)	149.3 (5.881)							–	–	–	–	–	–	-105400 (-23700)	-261 (-38.0)	

[1] L1 $[(0/\pm45/0/90)_S]_2$

WIDTH EFFECT TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L3-31 -13	L3 [1]	2.51 (.099)	47.3 (1.861)	5/8 FP SLIT	15.8 (.622)	15.9 (.626)	THRU	TENSION STATIC	ROOM	–	–	–	–	–	–	47590 (10700)	400 (58.0)	
-17	↓	2.64 (.104)	98.6 (3.882)	↓	15.9 (.628)	15.9 (.627)	↓	↓	↓	–	–	–	–	–	–	124100 (27900)	476 (69.1)	
-21	↓	2.64 (.104)	149.3 (5.880)	↓	16.1 (.633)	16.0 (.629)	↓	↓	↓	–	–	–	–	–	–	148100 (33300)	375 (54.4)	GRIP AREA FAILURE
-14	L3	2.56 (.101)	47.4 (1.865)	5/8 FP SLIT	15.8 (.621)	16.1 (.632)	THRU	COMPRESSION STATIC	ROOM	–	–	–	–	–	–	-33400 (-7500)	-274 (-39.9)	
-18	↓	2.62 (.103)	98.4 (3.874)	↓	16.0 (.630)	16.1 (.634)	↓	↓	↓	–	–	–	–	–	–	69400 (-15600)	-269 (-39.1)	
-22	↓	2.62 (.103)	149.4 (5.881)	↓	15.9 (.626)	16.1 (.634)	↓	↓	↓	–	–	–	–	–	–	-107600 (-24200)	-279 (-39.9)	
-15	L3	2.59 (.102)	50.0 (1.969)	IMPACT				TENSION STATIC	ROOM	–	–	–	–	–	–	122000 (27500)	943 (136.9)	
-19	↓	2.64 (.104)	99.9 (3.932)	↓				↓	↓	–	–	–	–	–	–	231000 (52000)	876 (127.0)	
-23	↓	2.69 (.106)	149.4 (5.882)	↓				↓	↓	–	–	–	–	–	–			
-16	L3	2.59 (.102)	50.2 (1.976)	IMPACT				COMPRESSION STATIC	ROOM	–	–	–	–	–	–	-41300 (-9300)	-317 (-46.0)	
-20	↓	2.69 (.106)	100.2 (3.945)	↓				↓	↓	–	–	–	–	–	–	-90100 (-20250)	-333 (-48.5)	
-24	↓	2.62 (.103)	149.4 (5.882)	↓				↓	↓	–	–	–	–	–	–	-114700 (-25800)	-293 (-42.6)	GRIP AREA FAILURE

[1] L3 · $[(0/+30/0^*/-30/0)_2]_s$ * S-GLASS PLY

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-21-1	L1 ▷	2.59 (.102)	76.2 (2.998)	NONE	0		—	PRELOAD STATIC	ROOM	95600 (21500)	484 (70.3)					164 000 (36 900)	831 (120.7)	
-2	↓	2.62 (.103)	76.2 (2.998)	↓	0		—	STATIC	ROOM	—	—					165 000 (37 200)	830 (120.5)	
-3	↓	2.64 (.104)	76.2 (2.998)	↓	0		—	STATIC	422 (300)	—	—					124 000 (27 800)	614 (89.2)	
-4	↓	2.57 (.101)	76.2 (2.999)	↓	0		—	PRELOAD STATIC	422 (300)	95600 (21500)	489 (71.0)					112 000 (25 200)	573 (83.2)	
-5	↓	2.62 (.103)	76.2 (2.998)	1/8 FP HOLE	3.18 (.125)		—	PRELOAD STATIC	ROOM	68100 (15200)	341 (49.5)					103 600 (23 300)	520 (75.5)	
-6	↓	2.54 (.100)	76.1 (2.997)	↓	3.15 (.125)		—	STATIC	ROOM	—	—					103 600 (23 300)	535 (77.7)	
-7	↓	2.57 (.101)	76.1 (2.997)	↓	3.30 (.130)		—	STATIC	422 (300)	—	—					113 000 (25 500)	580 (84.2)	
-8	↓	2.57 (.101)	76.1 (2.997)	↓	3.18 (.125)		—	PRELOAD STATIC	422 (300)	68100 (15300)	348 (50.5)					109 000 (24 500)	557 (80.9)	
-9	↓	2.64 (.104)	76.2 (2.999)	3/8 FP HOLE	9.53 (.375)		—	PRELOAD STATIC	ROOM	52000 (11700)	258 (37.5)					77 400 (17 400)	384 (55.8)	
-10	↓	2.62 (.103)	76.2 (2.998)	↓	9.65 (.380)		—	STATIC	ROOM	—	—					78 300 (17 600)	392 (57.0)	
-11	↓	2.62 (.103)	76.2 (2.998)	↓	9.65 (.380)		—	STATIC	422 (300)	—	—					93 900 (21 100)	470 (68.3)	
-12	↓	2.49 (.098)	76.2 (2.999)	↓	9.53 (.375)		—	PRELOAD STATIC	422 (300)	52000 (11700)	274 (39.8)					74 300 (16 700)	391 (56.8)	
-13	↓	2.59 (.102)	76.2 (2.999)	5/8 FP HOLE	15.9 (.625)		—	PRELOAD STATIC	ROOM	46300 (10400)	234 (34.0)					71600 (16100)	362 (52.6)	
-14	↓	2.62 (.103)	76.2 (2.999)	↓	16.3 (.640)		—	STATIC	ROOM	—	—					67600 (15 200)	339 (49.2)	
-15	↓	2.64 (.104)	76.2 (2.999)	↓	16.0 (.630)		—	STATIC	422 (300)	—	—					73400 (16 500)	364 (52.9)	
-16	↓	2.39 (.094)	76.2 (2.999)	↓	15.9 (.625)		—	PRELOAD STATIC	422 (300)	46300 (10400)	254 (36.9)					60900 (13700)	335 (48.6)	

▷ L1 · $[(0/\pm45/0/90)_s]_2$

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-21-17	L1	2.59 (.102)	76.2 (2.999)	3/8 CSK HOLE	9.53 (.375)			PRELOAD STATIC	ROOM	48000 (10800)	243 (35.3)					74700 (16800)	378 (54.9)	
-18		2.54 (.100)	76.2 (2.998)	1/8 CSK HOLE	3.15 (.125)			PRELOAD STATIC	ROOM	60900 (13700)	315 (45.7)					80500 (18100)	416 (60.4)	
-19		2.62 (.103)	76.2 (2.998)		3.30 (.130)			STATIC	ROOM	—	—					89400 (20100)	448 (65.1)	
-21		2.64 (.104)	76.0 (2.990)	1/8 FP SLIT	3.15 (.125)			PRELOAD STATIC	ROOM	70700 (15900)	352 (51.1)					99600 (22400)	496 (72.0)	
-22		2.64 (.104)	76.0 (2.991)		3.30 (.130)			STATIC	ROOM	—	—					97400 (21900)	485 (70.4)	
-23		2.69 (.106)	76.1 (2.996)		3.30 (.130)			STATIC	422 (300)	—	—					113 800 (25600)	555 (80.6)	
-24		2.62 (.103)	76.1 (2.997)		3.15 (.125)			PRELOAD STATIC	422 (300)	70700 (15900)	355 (51.3)					104 500 (23500)	524 (76.1)	
-25		2.67 (.105)	76.1 (2.997)	3/8 FP SLIT	9.65 (.380)			PRELOAD STATIC	ROOM	56 500 (12700)	278 (40.4)					84500 (19000)	416 (60.4)	
-26		2.67 (.105)	76.2 (2.998)		9.91 (.390)			STATIC	ROOM	—	—					77800 (17500)	383 (55.6)	
-27		2.64 (.104)	76.1 (2.997)		9.65 (.380)			STATIC	422 (300)	—	—					80500 (18100)	400 (58.1)	
-28		2.62 (.103)	76.1 (2.997)		9.65 (.380)			PRELOAD STATIC	422 (300)	56 500 (12700)	283 (41.1)					72 000 (16200)	362 (52.5)	
-29		2.69 (.106)	76.0 (2.993)	5/8 FP SLIT	16.0 (.630)			PRELOAD STATIC	ROOM	47 100 (10600)	230 (33.4)					67600 (15200)	330 (47.9)	
-30		2.67 (.105)	76.1 (2.997)		15.75 (.620)			STATIC	ROOM	—	—					62300 (14000)	307 (44.5)	
-31		2.67 (.105)	76.2 (2.998)		16.0 (.630)			STATIC	422 (300)	—	—					69800 (15700)	344 (49.9)	
-32		2.62 (.103)	76.2 (2.998)		16.0 (.630)			PRELOAD STATIC	422 (300)	47 100 (10600)	236 (34.3)					62300 (14000)	312 (45.3)	

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICK-NESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m^2 (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m^2 (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m^2 (KSI)	REMARKS
L1-21-33	L1	2.69 (.106)	76.2 (2.998)	5/8 CSK HOLE	16.3 (.640)			PRELOAD STATIC	ROOM	39600 (8900)	193 (28.0)					66700 (15000)	325 (47.2)	
-34		2.69 (.106)	76.2 (2.998)		16.0 (.630)			STATIC	ROOM	–	–					66700 (15000)	325 (47.2)	
-35		2.69 (.106)	76.2 (2.998)		16.3 (.640)			STATIC	422 (300)	–	–					68000 (15300)	331 (48.1)	
-36		2.62 (.103)	76.2 (2.998)		16.1 (.635)			PRELOAD STATIC	422 (300)	39600 (8900)	198 (28.8)					59600 (13400)	299 (43.4)	
-37		2.67 (.105)	76.2 (2.999)	3/8 CSK HOLE	9.91 (.390)			STATIC	ROOM	–	–					67600 (15200)	333 (48.3)	
-38		2.64 (.104)	76.2 (2.998)		9.91 (.390)			STATIC	422 (300)	–	–					82300 (18500)	408 (59.3)	
-39		2.67 (.105)	76.2 (2.998)		9.53 (.375)			PRELOAD STATIC	422 (300)	48000 (10800)	236 (34.3)					86700 (19500)	426 (61.9)	
-41		2.54 (.100)	76.1 (2.997)	1/8 HP HOLE	3.18 (.125)	0	1.5 (.06)	PRELOAD STATIC	ROOM	92100 (20700)	476 (69.1)					112080 (25200)	579 (84.1)	
-42		2.64 (.104)	76.1 (2.997)		3.05 (.120)	0	1.5 (.06)	STATIC	ROOM	–	–					121400 (27300)	603 (87.6)	
-43		2.62 (.103)	76.2 (2.998)		3.18 (.125)	0	1.5 (.06)	STATIC	422 (300)	–	–					119200 (26800)	598 (86.8)	
-44		2.62 (.103)	76.2 (2.998)		3.18 (.125)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	92100 20700	462 (67.0)					103600 (23300)	534 (77.5)	
-45		2.57 (.101)	76.1 (2.997)	1/8 HP SLIT	3.18 (.125)	0	1.5 (.06)	PRELOAD STATIC	ROOM	85000 (19100)	435 (63.1)					113400 (25500)	580 (84.2)	
-46		2.59 (.102)	76.1 (2.997)		3.18 (.125)	0	1.5 (.06)	STATIC	ROOM	–	–					113400 (25500)	575 (83.4)	
-47		2.62 (.103)	76.1 (2.997)		3.05 (.120)	0	1.5 (.06)	STATIC	422 (300)	–	–					125000 (28100)	627 (91.0)	
-48		2.64 (.104)	76.1 (2.997)		3.18 (.125)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	85000 (19100)	422 (61.3)					102300 (23000)	508 (73.8)	

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-21-49	L1	2.62 (.103)	76.2 (2.998)	3/8 HP HOLE	9.53 (.375)	0	1.5 (.06)	PRELOAD STATIC	ROOM	81400 (18300)	409 (59.3)					92100 (20700)	462 (67.0)	
-50		2.64 (.104)	76.2 (2.998)		9.40 (.370)	0	1.5 (.06)	STATIC	ROOM	–	–					102 300 (23000)	508 (73.8)	
-51		2.57 (.101)	76.2 (2.998)		9.53 (.375)	0	1.5 (.06)	STATIC	422 (300)	–	–					109 900 (24 700)	562 (81.6)	
-52		2.54 (.100)	76.2 (2.998)		9.53 (.375)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	81400 (18300)	420 (61.0)					101 900 (22 900)	526 (76.4)	
-53		2.62 (.103)	76.2 (2.998)	3/8 HP SLIT	9.53 (.375)	0	1.5 (.06)	PRELOAD STATIC	ROOM	76900 (17300)	386 (56.0)					105 400 (23700)	529 (76.8)	
-54		2.64 (.104)	76.1 (2.997)		9.40 (.370)	0	1.5 (.06)	STATIC	ROOM	–	–					116 500 (26200)	579 (84.1)	
-55		2.64 (.104)	76.2 (2.998)		9.40 (.370)	0	1.5 (.06)	STATIC	422 (300)	–	–					109 900 (24 700)	546 (79.2)	
-56		2.59 (.102)	76.1 (2.997)		9.40 (.370)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	76 900 (17300)	386 (56.0)					107 200 (24 100)	543 (78.8)	
-57		2.59 (.102)	76.2 (2.998)	1/8 CSK HOLE	3.30 (.130)			STATIC	422 (300)	–	–					108 500 (24400)	550 (79.8)	
-58		2.62 (.103)	76.2 (2.998)		3.18 (.125)			PRELOAD STATIC	422 (300)	60900 (13700)	306 (44.4)					110800 (24900)	555 (80.6)	
-59		2.62 (.103)	76.0 (2.993)	5/8 HP HOLE	15.9 (.625)	0	1.5 (.06)	PRELOAD STATIC	ROOM	71600 (16 100)	360 (52.2)					86700 (19500)	436 (63.3)	
-61		2.69 (.106)	76.1 (2.995)		15.8 (.620)	0	1.5 (.06)	STATIC	ROOM	–	–					94300 (21200)	460 (66.8)	
-62		2.67 (.105)	76.1 (2.996)		15.9 (.625)	0	1.5 (.06)	STATIC	422 (300)	–	–					87600 (19700)	431 (62.6)	
-63		2.69 (.106)	76.1 (2.996)	5/8 HP SLIT	16.3 (.640)	0	1.5 (.06)	PRELOAD STATIC	ROOM	78700 (17700)	384 (55.7)					103 200 (23200)	504 (73.1)	
-64		2.62 (.103)	76.1 (2.995)		16.5 (.650)	0	1.5 (.06)	STATIC	ROOM	–	–					86700 (19500)	435 (63.2)	

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICK-NESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-21-65	L1	2.69 (.106)	76.1 (2.997)	5/8 HP SLIT	16.5 (.650)	0	1.5 (.06)	STATIC	422 (300)	—	—					102300 (23000)	499 (72.4)	
-66	L1	2.69 (.106)	76.1 (2.997)		14.7 (.580)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	78700 (17700)	384 (55.7)					92100 (20700)	449 (65.2)	
-67	L1	2.72 (.107)	76.1 (2.996)	5/8 HP HOLE	15.9 (.625)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	71600 (16100)	346 (50.2)					93900 (21100)	453 (65.8)	

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICK-NESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L2-21-1	L2 [2]	2.59 (.102)	76.1 (2.995)	NONE	0			PRELOAD STATIC	ROOM	156100 (35100)	792 (114.9)					201000 (45200)	1020 (148.0)	
-2		2.69 (.106)	76.1 (2.995)		0			STATIC	ROOM	–	–					205000 (46200)	1002 (145.5)	
-3		2.69 (.106)	76.1 (2.996)		0			STATIC	422 (300)	–	–					171200 (38500)	835 (121.2)	
-4		2.69 (.106)	76.1 (2.997)		0			PRELOAD STATIC	422 (300)	156100 (35100)	761 (110.3)					177900 (40000)	867 (1 5.9)	
-5		2.62 (.103)	76.1 (2.997)	1/8 FP HOLE	3.18 (.125)			PRELOAD STATIC	ROOM	108500 (24400)	544 (79.0)					79100 (38000)	848 (123.1)	
-6		2.67 (.105)	76.2 (2.998)		3.05 (.120)			STATIC	ROOM	–	–					162300 (36500)	799 (116.0)	
-7		2.69 (.106)	76.1 (2.997)		3.18 (.125)			STATIC	422 (300)	–	–					137900 (31000)	672 (97.6)	
-8		2.72 (.107)	76.2 (2.998)		3.18 (.125)			PRELOAD STATIC	422 (300)	108500 (24400)	524 (76.1)					144600 (32500)	698 (101.3)	
-9		2.62 (.103	76.2 (2.998)	3/8 FP HOLE	9.53 (.375)			PRELOAD STATIC	ROOM	101900 (22900)	511 (74.2)					125900 (28300)	631 (91.6)	
-10		2.67 (.105)	76.1 (2.997)		9.65 (.380)			STATIC	ROOM	–	–					136100 (30600)	670 (97.2)	
-11		2.67 (.105)	76.1 (2.996)		9.65 (.380)			STATIC	422 (300)	–	–					116500 (26200)	572 (83.0)	
-12		2.69 (.106)	76.1 (2.997)		9.53 (.375)			PRELOAD STATIC	422 (300)	101900 (22900)	497 (72.1)					17400 (26400)	572 (83.1)	
-21		2.62 (.103)	76.2 (2.999)	5/8 FP HOLE	15.9 (.625)			PRELOAD STATIC	ROOM	78700 (17700)	395 (57.3)					109400 (24600)	548 (79.4)	
-22		2.67 (.105)	76.2 (2.999)		15.8 (.620)			STATIC	ROOM	–	–					121300 (27280)	597 (86.6)	
-23		2.69 (.106)	76.2 (3.000)		16.3 (.640)			STATIC	422 (300)	–	–					94700 (21300)	461 (67.0)	
-24		2.74 (.108)	76.2 (3.000)		15.9 (.625)			PRELOAD STATIC	422 (300)	78700 (17700)	376 (54.6)					101400 (22800)	485 (70.4)	

L2 $[(0_3/\pm 8C)_2]_s$

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	R	CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L2-21-25	L2 [2]	2.64 (.104)	76.2 (3.001)	5/8 FP SLIT	15.9 (.625)			PRELOAD STATIC	ROOM	86700 (19500)	431 (62.5)					103 200 (23 200)	512 (74.3)	
-26		2.72 (.107)	76.2 (3.001)		16.1 (.635)			STATIC	ROOM	–	–					110 300 (24 800)	532 (77.2)	
-27		2.69 (.106)	76.2 (3.004)		16.2 (.637)			STATIC	422 (300)	–	–					98 300 (22 100)	479 (69.5)	
-28		2.72 (.107)	76.3 (3.002)		15.5 (.610)			PRELOAD STATIC	422 (300)	86700 (19500)	418 (60.7)					106 700 (24000)	515 (74.7)	
-29		2.64 (.104)	76.2 (3.001)	5/8 HP SLIT	15.8 (.620)	0	1.5 (.06)	PRELOAD STATIC	ROOM	124500 (28 000)	601 (87.2)					163 700 (36 800)	790 (114.6)	
-30		2.69 (.106)	76.3 (3.003)		16.8 (.660)	0	1.5 (.06)	STATIC	ROOM	–	–					164600 (37000)	801 (116.3)	
-31		2.64 (.104)	76.3 (3.002)		15.8 (.620)	0	1.5 (.06)	STATIC	422 (300)	–	–					145 900 (32 800)	724 (105.1)	
-32		2.64 (.104)	76.1 (2.996)		16.5 (.650)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	124 500 (28000)	619 (89.9)					156 600 (35200)	779 (113.0)	
-41		2.69 (.106)	76.3 (3.002)	3/8 FP SLIT	9.6 (.378)			PRELOAD STATIC	ROOM	105 900 (23800)	515 (74.8)					139 200 (31 300)	678 (98.4)	
-42		2.64 (.104)	76.3 (3.002)		9.7 (.382)			STATIC	ROOM	–	–					132 100 (29 700)	655 (95.1)	
-43		2.79 (.110)	76.2 (2.999)		9.7 (.380)			STATIC	422 (300)	–	–					107 600 (24 200)	506 (73.4)	
-44		2.57 (.101)	76.1 (2.997)		9.7 (.383)			PRELOAD STATIC	422 (300)	105900 (23800)	541 (78.6)					106 800 (24 000)	546 (79.3)	
-45		2.72 (.107)	76.1 (2.996)	3/8 HP SLIT	9.6 (.380)	0	1.5 (.06)	PRELOAD STATIC	ROOM	143200 (32200)	692 (100.4)					197 900 (44 500)	956 (138.8)	
-46		2.72 (.107)	76.2 (2.998)		9.6 (.380)	0	1.5 (.06)	STATIC	ROOM	–	–					185 000 (41 600)	894 (129.7)	
-47		2.72 (.107)	76.1 (2.997)		9.6 (.380)	0	1.5 (.06)	STATIC	422 (300)	–	–					155 700 (35 000)	752 (109.1)	
-48		2.62 (.103)	76.1 (2.996)		9.6 (.380)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	143 200 (32 200)	719 (104.3)					155700 (35 000)	781 (113.4)	

[2] L2 . $[(0_8/\pm 80)_c]_s$

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L2-21 -49	L2 [2]	2.69 (.106)	76.1 (2.996)	1/8 FP SLIT	3.18 (.125)			PRELOAD STATIC	ROOM	110800 (24900)	540 (78.4)					182400 (41000)	889 (129.1)	
-50		2.67 (.105)	76.1 (2.995)		3.30 (.130)			STATIC	ROOM	–	–					146800 (33000)	722 (104.9)	
-51		2.62 (.103)	76.1 (2.994)		3.18 (.125)			STATIC	422 (300)	–	–					138300 (31100)	694 (100.8)	
-52		2.57 (.101)	76.2 (2.999)		3.18 (.125)			PRELOAD STATIC	422 (300)	110800 (24900)	566 (82.2)					141900 (31900)	725 (105.3)	
-61		2.72 (.107)	76.4 (3.006)	1/8 HP SLIT	3.05 (.120)	0	1.5 (.06)	PRELOAD STATIC	ROOM	119700 (26900)	576 (83.6)					209000 (47000)	1006 (146.1)	
-62		2.69 (.106)	76.3 (3.002)		3.18 (.125)	0	1.5 (.06)	STATIC	ROOM	–	–					203300 (45700)	989 (143.6)	
-63		2.67 (.105)	76.3 (3.003)		3.18 (.125)	0	1.5 (.06)	STATIC	422 (300)	–	–					164600 (37000)	808 (117.3)	
-64		2.57 (.101)	76.3 (3.004)		3.18 (.125)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	119700 (26900)	611 (88.7)					162400 (36500)	829 (120.3)	
L2-22 -1		2.67 (.105)	76.2 (3.001)	5/8 FP HOLE	15.88 (.625)			PRELOAD STATIC	ROOM	79200 (17800)	404 (58.7)					129900 (29200)	663 (96.2)	LOW PRESSURE CURE 345 kPa (50 psi)
-2		2.67 (.105)	76.2 (3.001)		15.88 (.625)			STATIC	ROOM	–	–					117000 (26300)	576 (83.6)	
-3		2.72 (.107)	76.3 (3.002)		15.88 (.625)			STATIC	422 (300)	–	–					102300 (23000)	493 (71.6)	
-4		2.62 (.103)	76.3 (3.002)		15.85 (.624)			PRELOAD STATIC	422 (300)	79200 (17800)	397 (57.6)					93400 (21000)	468 (67.9)	
L2-23 -1		2.69 (.106)	76.2 (3.001)	5/8 FP HOLE	15.88 (.625)			PRELOAD STATIC	ROOM	80900 (18200)	394 (57.2)					119200 (26800)	580 (84.2)	LOW PRESSURE CURE 172 kPa (25 psi)
-2		2.74 (.108)	76.3 (3.003)		15.88 (.625)			STATIC	ROOM	–	–					120100 (27000)	574 (83.3)	
-3		2.74 (.108)	76.2 (3.001)		15.88 (.625)			STATIC	422 (300)	–	–					90700 (20400)	433 (62.9)	
-4		2.69 (.106)	76.3 (3.002)		15.88 (.625)			PRELOAD STATIC	422 (300)	80950 (18200)	394 (57.2)					92100 (20700)	449 (65.1)	

[2] L2 $[(0_2/\pm 80)_2]_s$

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICK-NESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m^2 (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m^2 (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m^2 (KSI)	REMARKS
L2-24 -1	[2] L2	2.74 (.108)	76.2 (3.000)	5/8 FP HOLE	15.9 (.625)			PRELOAD STATIC	ROOM	89800 (20200)	429 (62.3)					129000 (29000)	617 (89.5)	LOW PRESSURE CURE 86 kPa (12.5 psi)
-2		2.74 (.108)	76.3 (3.002)		15.9 (.625)			STATIC	ROOM	—	—					115200 (25900)	551 (79.9)	
-3		2.74 (.108)	76.2 (3.001)		15.9 (.625)			STATIC	422 (300)	—	—					95600 (21500)	457 (66.3)	
-4		2.64 (.104)	76.2 (3.001)		15.9 (.625)			PRELOAD STATIC	422 (300)	89800 (20200)	446 (64.7)					89800 (20200)	446 (64.7)	
L3-21 -1	[3] L3	2.62 (.103)	76.3 (3.002)	1/8 FP SLIT	3.18 (.125)			PRELOAD STATIC	ROOM	105000 (23600)	526 (76.3)					136600 (30700)	684 (99.3)	
-2		2.57 (.101)	76.3 (3.002)		3.18 (.125)			STATIC	ROOM	—	—					128500 (28900)	657 (95.3)	
-3		2.57 (.101)	76.2 (3.001)		3.18 (.125)			STATIC	422 (300)	—	—					134300 (30200)	686 (99.6)	
-4		2.49 (.098)	76.3 (3.002)		3.18 (.125)			PRELOAD STATIC	422 (300)	105000 (23600)	553 (80.2)					120100 (27000)	633 (91.8)	
-5		2.62 (.103)	76.2 (3.001)	3/8 FP SLIT	9.65 (.380)			PRELOAD STATIC	ROOM	81400 (18300)	408 (59.2)					98300 (22100)	493 (71.5)	
-6		2.57 (.101)	76.3 (3.003)		9.65 (.380)			STATIC	ROOM	—	—					100000 (22500)	511 (74.2)	
-7		2.57 (.101)	76.2 (3.001)		9.90 (.380)			STATIC	422 (300)	—	—					104500 (23500)	534 (77.5)	
-8		2.49 (.098)	76.3 (3.002)		9.65 (.380)			PRELOAD STATIC	422 (300)	81900 (18300)	429 (62.2)					84500 (19000)	445 (64.6)	
-9		2.59 (.102)	76.3 (3.002)	5/8 FP SLIT	15.9 (.625)			PRELOAD STATIC	ROOM	69800 (15700)	353 (51.3)					87600 (19700)	443 (64.3)	
-10		2.62 (.103)	76.2 (3.001)		15.7 (.620)			STATIC	ROOM	—	—					89000 (20000)	446 (64.7)	
-11		2.51 (.099)	76.3 (3.002)		15.9 (.625)			STATIC	422 (300)	—	—					82700 (18600)	431 (62.6)	
-12		2.49 (.098)	76.2 (3.001)		15.9 (.625)			PRELOAD STATIC	422 (300)	69800 (15700)	368 (53.4)					81400 (18300)	428 (62.2)	

[2] L2 $[(0_3/\pm 80)_2]_s$

[3] L3 $[(0/+30/0^*/-30/0)_2]_s$ * S-GLASS PLY

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	R	CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L3-21 -21	L3 [3]	2.51 (.099)	76.6 (3.016	1/8 HP SLIT	2.79 (.110)	0	1.5 (.06)	PRELOAD STATIC	ROOM	134800 (30300)	699 (101.5)					153 500 (34500)	796 (115.5)	
-22		2.54 (.100)	76.2 (3.001)		2.79 (.110)	0	1.5 (.06)	STATIC	ROOM	—	—					157500 (35400)	813 (118.0)	
-23		2.59 (.102)	76.2 (3.000)		2.79 (.110)	0	1.5 (.06)	STATIC	422 (300)	—	—					132100 (29700)	669 (97.1)	
-24		2.56 (.101)	76.2 (3.001)		2.79 (.110)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	134800 (30300)	689 (100.0)					123200 (27700)	630 (91.4)	
-25		2.49 (.098)	76.2 (2.999)	3/8 HP SLIT	9.65 (.380)	0	1.5 (.06)	PRELOAD STATIC	ROOM	128100 (28800)	675 (98.0)					149000 (33 500)	785 (114.0)	
-26		2.59 (.102)	76.2 (3.001)		9.65 (.380)	0	1.5 (.06)	STATIC	ROOM	—	—					166800 (37500)	844 (122.5)	
-27		2.56 (.101)	76.2 (3.001)		10.2 (.400)	0	1.5 (.06)	STATIC	422 (300)	—	—					131200 (29 500)	670 (97.3)	
-28		2.51 (.099)	76.3 (3.003)		9.65 (.380)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	128100 (28800)	668 (96.9)					122 800 (27600)	639 (92.8)	
-29		2.49 (.098)	76.3 (3.002)	6/8 HP SLIT	15.9 (.620)	0	1.5 (.06)	PRELOAD STATIC	ROOM	122300 (27500)	644 (93.5)					131 700 (29600)	693 (100.6)	
-30		2.59 (.102)	76.2 (3.001)		15.7 (.620)	0	1.5 (.06)	STATIC	ROOM	—	—					174 800 (39300)	885 (128.4)	
-31		2.56 (.101)	76.3 (3.002)		16.0 (.630)	0	1.5 (.06)	STATIC	422 (300)	—	—					94300 (21200)	482 (69.9)	
-32		2.56 (.101)	76.3 (3.004)		16.3 (.640)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	122 300 (27500)	624 (90.6)					116 100 (26 100)	592 (86.0)	
-41		2.59 (.102)	76.2 (2.999)	1/8 FP HOLE	3.15 (.125)			PRELOAD STATIC	ROOM	106 700 (24 000)	541 (78.5)					134 300 (30200)	680 (98.7)	
-42		2.59 (.102)	76.2 (2.999)		3.15 (.125)			STATIC	ROOM	—	—					133 900 (30 100)	678 (98.4)	
-43		2.54 (.100)	76.2 (3.001)		3.15 (.125)			STATIC	422 (300)	—	—					120 100 (27000)	620 (90.0)	
-44		2.46 (.097)	76.2 (3.001)		3.15 (.125)			PRELOAD STATIC	422 (300)	106 700 (24000)	568 (82.4)					123 700 (27 800)	658 (95.5)	

[3] L3 $[(0/+30/0^{*}/-30/0)_2]_s$ * S-GLASS PLY

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L3-21 -45	L3 [13]	2.59 (.102)	76.2 (3.000)	3/8 FP HOLE	9.53 (.375)			PRELOAD STATIC	ROOM	80500 (18100)	408 (59.2)					103600 (23300)	524 (76.1)	
-46	↓	2.59 (.102)	76.2 (3.000)	↓	9.65 (.380)			STATIC	ROOM	—	—					97400 (21900)	493 (71.6)	
-47	↓	2.59 (.102)	76.2 (3.000)	↓	9.65 (.380)			STATIC	422 (300)	—	—					112500 (25300)	570 (82.7)	
-48	↓	2.49 (.098)	76.2 (3.001)	↓	9.53 (.375)			PRELOAD STATIC	422 300	80500 (18100)	424 (61.5)					90700 (20400)	478 (69.4)	
-49	↓	2.59 (.102)	76.2 (3.001)	5/8 FP HOLE	15.9 (.625)			PRELOAD STATIC	ROOM	67200 (15100)	340 (49.3)					81600 (18350)	413 (59.9)	
-50	↓	2.59 (.102)	76.3 (3.002)	↓	15.9 (.625)			STATIC	ROOM	—	—					88500 (19900)	448 (65.0)	
-51	↓	2.51 (.099)	76.2 (3.001)	↓	15.9 (.625)			STATIC	422 (300)	—	—					81400 (18300)	424 (61.6)	
-52	↓	2.49 (.098)	76.3 (3.004)	↓	15.9 (.625)			PRELOAD STATIC	422 (300)	67200 (15100)	353 (51.3)					81400 (18300)	428 (62.2)	
-61	↓	2.51 (.099)	76.2 (2.998)	NO DEFECT	0	0		PRELOAD STATIC	ROOM	170400 (38300)	889 (129.0)					200100 (45000)	1044 (151.5)	
-62	↓	2.56 (.101)	76.2 (2.999)	↓	0	0		STATIC	ROOM	—	—					208000 (46900)	1067 (154.8)	
-63	↓	2.59 (.102)	76.2 (2.998)	↓	0	0		STATIC	422 (300)	—	—					146800 (33000)	743 (107.9)	
-64	↓	2.56 (.101)	76.2 (2.999)	↓	0	0		PRELOAD STATIC	422 (300)	170400 (38300)	871 (126.4)					139200 (31300)	712 (103.3)	
L3-22 -1	L3-2 [14]	2.67 (.105)	76.2 (2.999)	5/8 HP SLIT	15.9 (.625)	0	1.5 (.06)	PRELOAD STATIC	ROOM	96500 (21700)	493 (71.6)					175700 (39500)	898 (130.4)	
-2	↓	2.69 (.106)	76.2 (2.999)	↓	15.9 (.625)	0	1.5 (.06)	STATIC	ROOM	—	—					158800 (35700)	774 (112.3)	
-3	↓	2.72 (.107)	76.2 (3.000)	↓	16.0 (.630)	0	1.5 (.06)	STATIC	422 (300)	—	—					163700 (36800)	789 (114.6)	
-4	↓	2.69 (.106)	76.2 (3.000)	↓	15.7 (.620)	0	1.5 (.06)	PRELOAD STATIC	422 (300)	96500 (21700)	470 (68.2)					145000 (32600)	706 (102.5)	

[13] L3 $[(0/+30/0^{*}/-30/0)_2]_s$ * S-GLASS PLY

[14] L3-2 $[(0/+30/0/-30/0)_2]_s$ ALL GRAPHITE LAMINATE

WET SPECIMEN STATIC TEST DATA

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L3-22-5	[4] L3-2	2.74 (.108)	76.2 (2.999)	5/8 FP SLIT	15.9 (.625)			PRELOAD STATIC	Room	54300 (12200)	260 (37.7)					106300 (23900)	508 (73.8)	
-6		2.64 (.104)	76.2 (3.000)		16.3 (.640)			STATIC	Room	—	—					116100 (26100)	577 (83.7)	
-7		2.74 (.108)	76.2 (3.000)		16.3 (.640)			STATIC	422 (300)	—	—					93000 (20900)	444 (64.5)	
-8		2.62 (.103)	76.2 (3.000)		16.0 (.630)			PRELOAD STATIC	422 (300)	54300 (12200)	272 (39.5)					83200 (18700)	417 (60.5)	
-9		2.74 (.108)	76.3 (3.003)	NO DEFECT	0			STATIC	Room	—	—					245000 (55100)	1171 (169.9)	
-21		2.67 (.105)	76.3 (3.002)	5/8 FP HOLE	15.9 (.625)			PRELOAD STATIC	Room	54300 (12200)	267 (38.7)					98800 (22200)	485 (70.4)	
-22		2.67 (.105)	76.2 (3.001)		15.9 (.625)			STATIC	Room	—	—					101400 (22800)	499 (72.4)	
-23		2.72 (.107)	76.2 (3.001)		15.9 (.625)			STATIC	422 (300)	—	—					94300 (21200)	455 (66.0)	
-24		2.64 (.104)	76.3 (3.002)		15.9 (.625)			PRELOAD STATIC	422 (300)	54300 (12200)	269 (39.1)					85400 (19200)	424 (61.5)	

[4] L3-2 $[(0/+30/0/-30/0)_2]_S$ ALL GRAPHITE PLIES

CYCLIC DATA

ROOM TEMPERATURE DRY TESTS

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-31 -80	L1 [1]	2.84 (.1118)	75.0 (2.9518)	5/8 FP HOLE	15.9 (.626)	–	THRU	CYCLIC	ROOM	–	–	46700 (10500)	207 (30.1)	0.05	10^6	71600 (16100)	336 (48.8)	
-81		2.73 (.1075)	76.1 (2.9957)		15.9 (.626)	–				–	–	46700 (10500)	224 (32.6)		10^7	81200 (18250)	390 (56.7)	
-74		2.79 (.1097)	74.6 (2.9370)		15.9 (.626)	–		PRELOAD CYCLIC		48900 (11000)	235 (34.1)	46700 (10500)	224 (32.6)		10^7	77800 (17500)	374 (54.3)	
-35		2.77 (.1090)	74.5 (2.9345)	5/8 FP SLIT	16.1 (.635)	15.9 (.625)	THRU	CYCLIC		–	–	46700 (10500)	226 (32.8)	0.05	10^6	66700 (15000)	323 (46.9)	
-36		2.81 (.1107)	75.2 (2.9608)		16.2 (.637)	15.9 (.628)				–	–	46700 (10500)	220 (32.0)		7×10^6	–	–	COMPRESSIVE OVERLOAD FAILING SPECIMEN
-54		2.78 (.1095)	75.0 (2.9514)		16.1 (.635)	15.9 (.625)		PRELOAD CYCLIC		48900 (11000)	234 (34.0)	46700 (10500)	223 (32.5)		10^7	77600 (17450)	372 (54.0)	
-85		2.78 (.1095)	74.3 (2.9249)	5/8 FP HOLE	15.9 (.626)	–	THRU	CYCLIC		–	–	40000 (9000)	193 (28.1)	-1.0	12970 [3]	–	–	
-86		2.82 (.1110)	76.4 (3.0084)		15.9 (.627)	–				–	–	37800 (8500)	175 (25.5)		12320 [3]	–	–	
-77		2.81 (.1108)	76.3 (3.0034)		16.0 (.629)	–		PRELOAD CYCLIC		48900 (11000)	227 (33.1)	37800 (8500)	175 (25.5)		70000 [3]	–	–	
-40		2.81 (.1105)	74.9 (2.9500)	5/8 FP SLIT	15.9 (.626)	16.1 (.632)	THRU	CYCLIC		–	–	40000 (9000)	190 (27.6)	-1.0	10730 [3]	–	–	
-41		2.84 (.1120)	75.0 (2.9546)		15.9 (.626)	16.1 (.636)				–	–	37800 (8500)	176 (25.7)		219320 [3]	–	–	
-57		2.73 (.1075)	75.2 (2.9613)		16.2 (.637)	16.0 (.630)		PRELOAD CYCLIC		48900 (11000)	238 (34.6)	37800 (8500)	183 (26.7)		16700 [3]	–	–	

[1] L1 – $[(0/\pm 45/0/90)_S]_2$

[3] FAILURE DURING FATIGUE TEST

CYCLIC DATA

ROOM TEMPERATURE WET TESTS

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-31-64	L1 [1]	2.87 (.1130)	75.1 (2.9555)	5/8 FP HOLE	15.9 (.627)	–	THRU	CYCLIC	ROOM TEMP	–	–	46 700 (10 500)	216 (31.4)	0.05	10^3	71 600 (16100)	332 (48.2)	
-65		2.88 (.1135)	74.8 (2.943)		15.8 (.624)	–				–	–	46 700 (10 500)	216 (31.4)		10^6	77100 (17 325)	357 (51.9)	
-90		2.84 (.1120)	76.3 (3.003)		15.9 (.625)	–				–	–	46 700 (10 500)	215 (31.2)		10^7	79 100 (17 775)	364 (52.8)	
-66		2.79 (.1097)	75.2 (2.961)		15.9 (.626)	–		PRELOAD CYCLIC		48900 (11000)	233 (33.9)	46 700 (10 500)	222 (32.3)		10^3	71 500 (16 075)	340 (49.5)	
-67		2.75 (.1084)	74.6 (2.938)		15.9 (.626)					48 900 (11 000)	237 (34.5)	46 700 (10 500)	227 (33.0)		10^6	76500 (17 200)	372 (54.0)	
L1-31-25		2.77 (.1090)	75.0 (2.951)	5/8 FP SLIT	16.7 (.658)	16.6 (.654)		CYCLIC		–	–	46 700 (10 500)	224 (32.6)		10^3	63200 (14 225)	304 (44.2)	
-26		2.81 (.1105)	74.8 (2.946)		16.1 (.635)	15.8 (.622)				–	–	46 700 (10 500)	222 (32.3)		10^6	74800 (16 825)	356 (51.7)	
-27		2.78 (.1095)	75.2 (2.961)		16.0 (.630)	16.2 (.638)				–	–	46 700 (10 500)	223 (32.4)		10^7	76500 (17 200)	365 (53.0)	
-46		2.74 (.1079)	74.6 (2.938)		16.2 (.636)	16.0 (.629)		PRELOAD CYCLIC		48900 (11000)	239 (34.7)	46 700 (10 500)	228 (33.1)		10^5	76400 (17175)	373 (54.2)	
-47		2.73 (.1075)	75.1 (2.956)		16.2 (.638)	16.1 (.632)				48900 (11000)	238 (34.6)	46 700 (10 500)	227 (33.0)		10^6	80600 (18125)	392 (57.0)	

L1 $[(0/\pm45/0/90)_s]_2$

CYCLIC DATA

ROOM TEMPERATURE WET TESTS

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m^2 (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m^2 (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m^2 (KSI)	REMARKS
L1-31 - 94	L1 [1]	2.86 (.1125)	76.4 (3.007)	5/8 FP HOLE	15.8 (.623)	—	THRU	CYCLIC	ROOM TEMP	—	—	40 000 (9000)	183 (26.6)	-1.0	10^3	64800 (14575)	296 (43.1)	
- 95		2.83 (.1115)	76.0 (2.992)		15.9 (.625)	—				—	—	40 000 (9000)	185 (27.0)		450 [3]	—	—	
- 96		2.86 (.1125)	75.1 (2.956)		15.8 (.624)	—				—	—	37800 (8500)	176 (25.6)		1 350 [3]	—	—	
- 70		2.83 (.1116)	75.2 (2.960)		15.9 (.626)	—		PRELOAD CYCLIC		48900 (11 000)	229 (33.3)	40 000 (9000)	187 (27.2)		10^3	69800 (15700)	327 (47.5)	
- 71		2.71 (.1066)	76.1 (2.997)		15.9 (.627)	—				48900 (11 000)	237 (34.4)	40000 (9000)	194 (28.2)		1250 [3]	—	—	
L1-31 - 31		2.78 (.1095)	75.1 (2.959)	5/8 FP SLIT	16.1 (.632)	15.9 (.627)	THRU	CYCLIC		—	—	40000 (9000)	191 (27.8)	-1.0	750 [3]	—	—	
- 32		2.81 (.1105)	75.1 (2.958)		16.1 (.634)	16.0 (.630)				—	—	40000 (9000)	189 (27.5)		650 [3]	—	—	
- 33		2.86 (.1125)	75.0 (2.953)		16.1 (.635)	16.0 (.630)				—	—	37 800 (8500)	176 (25.6)		2 800 [3]	—	—	
- 50		2.77 (.1090)	75.1 (2.955)		16.2 (.639)	15.9 (.626)		PRELOAD CYCLIC		48900 (11000)	235 (34.2)	40000 (9000)	192 (27.9)		750 [3]	—	—	
- 51		2.82 (.1112)	74.4 (2.931)		15.8 (.623)	16.0 (.630)				48900 (11 000)	232 (33.7)	40000 (9000)	190 (27.6)		1100 [3]	—	—	

[1] L1 - $[(0/\pm45/0/90)_s]_2$

[3] FAILURE DURING CYCLIC TEST

CYCLIC DATA

422K (300 °F) [2] DRY TESTS

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-31 -82	L1 [1]	2.85 (.1123)	74.7 (2.939)	5/8 FP HOLE	15.9 (.625)		THRU	CYCLIC	422 [2] (300)	—	—	46700 (10500)	219 (31.8)	0.05	10^3	73200 (16450)	343 (49.8)	
-83		2.75 (.1084)	74.9 (2.949)		15.9 (.625)					—	—	46700 (10500)	226 (32.8)		10^6	87100 (19575)	421 (61.2)	
-84		2.81 (.1106)	74.8 (2.945)		15.9 (.626)					—	—	46700 (10500)	222 (32.2)		10^7	77400 (17400)	368 (53.4)	
-75		2.81 (.1106)	74.5 (2.933)		15.9 (.626)			PRELOAD CYCLIC		48900 (11000)	234 (34.0)	46700 (10500)	223 (32.4)		10^3	74600 (16775)	356 (51.7)	
-76		2.78 (.1093)	75.2 (2.961)		15.9 (.626)					48900 (11000)	234 (34.0)	46700 (10500)	223 (32.4)		10^6	75300 (16925)	360 (52.3)	
L1-31 -37		2.82 (.1112)	75.0 (2.951)	5/8 FP SLIT	16.0 (.629)	16.1 (.634)	THRU	CYCLIC	422 [2] (300)	—	—	46700 (10500)	220 (32.0)	0.05	10^3	69400 (15600)	327 (47.5)	
-38		2.74 (.1080)	74.3 (2.926)		16.1 (.636)	16.0 (.629)				—	—	46700 (10500)	228 (33.2)		10^6	94000 (21125)	460 (66.8)	
-39		2.79 (.1100)	75.1 (2.956)		15.8 (.622)	16.2 (.639)				—	—	46700 (10500)	222 (32.3)		2 008 100	—	—	COMPRESSIVE OVERLOAD DURING CYCLIC LOADING
-55		2.75 (.1085)	75.0 (2.951)		16.1 (.634)	15.9 (.627)		PRELOAD CYCLIC		48900 (11000)	236 (34.4)	46700 (10500)	225 (32.8)		10^3	65500 (14725)	316 (46.0)	
-56		2.70 (.1063)	74.9 (2.950)		16.2 (.639)	16.0 (.631)				—	—	—	—		—	—	—	STATIC FAILURE DURING PRELOAD
-61		2.74 (.1080)	75.0 (2.954)		16.2 (.637)	16.0 (.631)				48900 (11000)	237 (34.5)	46700 (10500)	226 (32.9)		10^6	82100 (18450)	398 (57.8)	

[1] L1 - $[(0/\pm 45/0/90)_s]_2$

[2] CYCLIC TEST TEMPERATURE - ROOM TEMPERATURE STATIC

CYCLIC DATA [2]

422 K (300 °F) DRY TESTS

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m^2 (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m^2 (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m^2 (KSI)	REMARKS
L1-31 -87	L1 [1]	2.86 (.1127)	74.5 (2.934)	5/8 FP HOLE	15.9 (.628)		THRU	CYCLIC	422 (300) [2]	–	–	40000 (9000)	187 (27.2)	-1.0	117 [3]	–	–	
-88		2.77 (.1090)	76.1 (2.998)		15.9 (.625)					–	–	40000 (9000)	189 (27.5)		1700 [3]	–	–	
-89		2.80 (.1101)	75.1 (2.956)		15.9 (.625)					–	–	37800 (8500)	179 (26.1)		41 [3]	–	–	
-78		2.75 (.1081)	74.3 (2.927)		15.9 (.626)			PRELOAD CYCLIC		48900 (11000)	239 (34.8)	40000 (9000)			197 [3]	–	–	
-79		2.78 (.1095)	76.4 (3.007)		15.9 (.626)					48900 (11000)	230 (33.4)	40000 (9000)	188 (27.3)		25 [2]	–	–	
L1-31 -42	L1 [1]	2.73 (.1075)	75.1 (2.959)	5/8 FP SLIT	16.3 (.640)	16.1 (.633)	THRU	CYCLIC	422 (300) [2]	–	–	40000 (9000)	194 (28.3)	-1.0	25 [3]	–	–	
-43		2.77 (.1092)	75.0 (2.954)		16.2 (.638)	16.3 (.643)				–	–	40000 (9000)	192 (27.9)		1750 [3]	–	–	
-44		2.77 (.1092)	75.0 (2.952)		16.2 (.638)	16.0 (.628)				–	–	37800 (8500)	181 (26.4)		1550 [3]	–	–	
-58		2.76 (.1085)	75.2 (2.959)		16.0 (.628)	16.2 (.636)		PRELOAD CYCLIC		48900 (11000)	236 (34.3)	40000 (9000)	193 (28.0)		3 [3]	–	–	
-59		2.79 (.1098)	75.2 (2.962)		16.1 (.632)	15.9 (.626)				48900 (11000)	233 (33.8)	39100 (8800)	186 (27.1)		2 [3]	–	–	

[1] L1 - $[(0/\pm45/0/90)_s]_2$

[2] CYCLIC TEST TEMPERATURE - ROOM TEMPERATURE STATIC

[3] FAILURE DURING FATIGUE TEST

CYCLIC DATA

422 K (300°F) [2] WET TESTS

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-31 -91	L1 [1]	2.87 (.1131)	76.3 (3.004)	5/8 FP HOLE	15.9 (.625)		THRU	CYCLIC	422 [2] (300)	—	—	46700 (10500)	212 (30.9)	0.05	10^3	81300 (18275)	370 (53.8)	
-92		2.82 (.1110)	75.0 (2.954)		15.8 (.624)					—	—	46700 (10500)	220 (32.0)		10^6	76800 (17275)	362 (52.7)	
-93		2.85 (.1123)	78.7 (3.100)		15.9 (.625)					—	—	46700 (10500)	207 (30.2)		10^7	91400 (20540)	406 (59.0)	
-68		2.77 (.1091)	76.0 (2.992)		15.9 (.626)			PRELOAD CYCLIC		48900 (11000)	230 (33.5)	46700 (10500)	220 (32.0)		10^3	74800 (16825)	353 (51.3)	
-69		2.78 (.1094)	74.9 (2.949)		15.9 (.626)					48900 (11000)	234 (34.1)	46700 (10500)	224 (32.5)		11	—	—	COMPRESSIVE OVERLOAD DURING FATIGUE TEST
L1-31 -28	L1 [1]	2.73 (.1074)	75.3 (2.964)	5/8 FP SLIT	16.2 (.639)	16.0 (.629)	THRU	CYCLIC	422 [2] (300)	—	—	46700 (10500)	227 (33.0)	0.05	10^3	74640 (16780)	363 (52.7)	
-29		2.68 (.1056)	75.2 (2.960)		15.9 (.626)	16.1 (.633				—	—	46700 (10500)	231 (33.6)		10^6	83500 (18780)	413 (60.1)	
-30		2.69 (.1060)	75.2 (2.960)		16.0 (.628)	16.1 (.633)				—	—	46700 (10500)	230 (33.5)		10^2	—	—	COMPRESSIVE OVERLOAD DURING FATIGUE TEST
-48		2.86 (.1125)	74.9 (2.948)		16.1 (.634)	16.0 (.628)		PRELOAD CYCLIC		48900 (11000)	228 (33.2)	46700 (10500)	218 (31.7)		10^3	84500 (19000)	394 (57.3)	
-49		2.72 (.1070)	74.9 (2.950)		16.1 (.634)	15.9 (.627)				48900 (11000)	240 (34.8)	46700 (10500)	229 (33.3)		10^6	83200 (18700)	408 (59.2)	

[1] L1 - $[(0/\pm 45/0/90)]_{s2}$

[2] CYCLIC TEST TEMPERATURE - ROOM TEMPERATURE STATIC

CYCLIC DATA [2]

422 K (300 °F) WET TESTS

SPEC. NO.	LAYUP	THICKNESS mm (INCH)	WIDTH mm (INCH)	FLAW TYPE	FLAW LENGTH FRONT mm (INCH)	FLAW LENGTH BACK mm (INCH)	FLAW DEPTH mm (INCH)	TEST TYPE	TEST TEMP. °K (°F)	PRELOAD LOAD N (LB)	PRELOAD STRESS MN/m² (KSI)	CYCLIC LOADING MAX LOAD N (LB)	CYCLIC LOADING MAX STRESS MN/m² (KSI)	CYCLIC LOADING R	CYCLIC LOADING CYCLES	RESIDUAL STATIC LOAD N (LB)	RESIDUAL STATIC STRESS MN/m² (KSI)	REMARKS
L1-31 -97	L1 [1]	2.83 (.1113)	74.6 (2.937)	5/8 FP HOLE	16.1 (.632)		THRU	CYCLIC	422 (300) [2]	—	—	13300 (3000)	63 (9.17)	-1.0	10^3	61100 (13730)	289 (42.1)	
-98		2.88 (.1133)	75.2 (2.959)		15.9 (.626)					—	—	13300 (3000)	61 (8.94)		642500	—	—	OVERLOAD + (15,700) − (7110)
-99		2.88 (.1134)	75.9 (2.989)		15.8 (.624)					—	—	13300 (3000)	60 (8.85)		10^7	78300 (17600)	357 (51.9)	
-72		2.73 (.1075)	75.2 (2.961)		16.0 (.630)			PRELOAD CYCLIC		48900 (11000)	238 (34.6)	13300 (3000)	64 (9.42)		10^3	57900 (13025)	281 (40.9)	
-73		2.77 (.1093)	74.3 (2.925)		15.9 (.626)					48900 (11000)	237 (34.4)	13300 (3000)	64 (9.38)		10^6	64500 (14500)	312 (45.3)	
L1-31 -34	L1 [1]	2.88 (.1135)	75.2 (2.962)	5/8 FP SLIT	16.1 (.635)	16.0 (.628)	THRU	CYCLIC	422 (300) [2]	—	—	26700 (6000)	122 (17.8)	-1.0	2 [3]	—	—	
-45		2.69 (.1061)	74.8 (2.944)		16.2 (.636)	16.0 (.628)				—	—	28900 (6500)	143 (20.8)		1 [3]	—	—	
-60		2.81 (.1106)	74.7 (2.942)		16.0 (.631)	16.2 (.638)				—	—	21800 (4910)	103 (15.1)		1 [3]	—	—	CYCLIC LOAD {+21840 (4910) −21900 (4930)
-32		2.81 (.1105)	75.1 (2.955)		15.9 (.627)	16.0 (.630)		PRELOAD CYCLIC		48900 (11000)	232 (33.7)	33800 (7600)	160 (23.3)		3 [3]	—	—	CYCLIC LOAD {+33800 (7600) −34500 (7750)
-53		2.72 (.1070)	74.9 (2.948)		16.1 (.632)	15.9 (.626)				48900 (11000)	240 (34.9)	13300 (3000)	65 (9.51)		10^6	74200 (16670)	364 (52.8)	
L1-31 -100	L1 [1]	2.78 (.1096)	75.2 (2.9610)	5/8 FP HOLE	15.9 (.625)		THRU	STATIC	422 (300) [5]	—	—	—	—	—	—	-20100 (-4510)	-95 (-13.9)	COMPRESSION STATIC TEST

[1] L1 - $[(0/\pm45/0/90)_s]_2$

[2] CYCLIC TEST TEMPERATURE - ROOM TEMPERATURE STATIC

[3] FAILURE DURING FATIGUE TEST

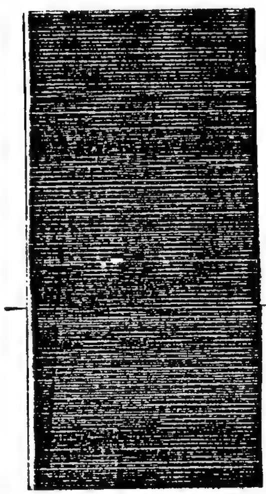
[5] SPECIMEN L1-31-100 STATIC TESTED AT 300 °F WET CONDITION

APPENDIX B

WIDTH EFFECT TEST SPECIMEN GROWTH DATA

This appendix contains the ultrasonic scan and crack opening displacement COD data for the width effect tests. Since some of these tests were compression loaded, the COD record indicates closing displacement.

ULTRASONIC C-SCAN DATA



NO PRELOAD

BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

MAXIMUM LOAD _____

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

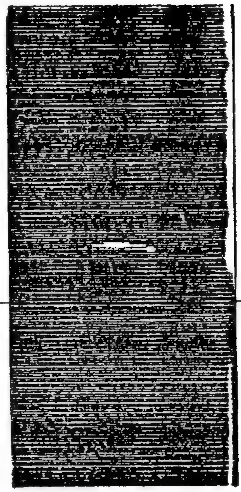
LAMINATE _____

SPECIMEN NO. LI-31A-1

DEFECT _____

TEST TYPE _____

ULTRASONIC C-SCAN DATA



BEFORE TEST

NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD ____________

AFTER MOISTUR[illegible]URE CONDITIONING

CYCLIC LOAD ____________

R RATIO ____________

TEST TEMPERA[illegible]RATL

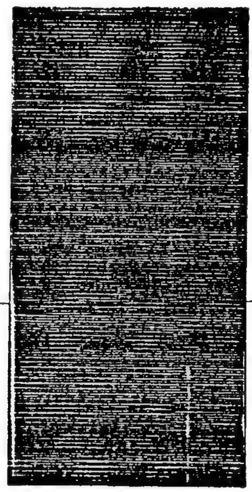
LAMINATE ____________

SPECIMEN NO. L1-31A-2

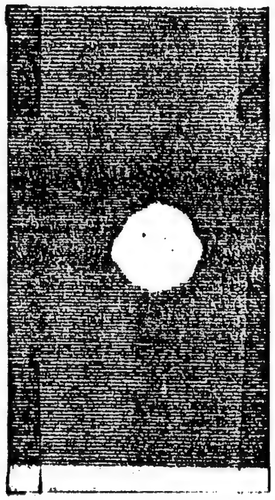
DEFECT ____________

TEST TYPE ____________

ULTRASONIC C-SCAN DATA



BEFORE TEST



~~AFTER PRELOAD~~
AFTER IMPACT

MAXIMUM LOAD 30 IN-LB

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

LAMINATE _____

SPECIMEN NO. L1-31A-3

DEFECT _____

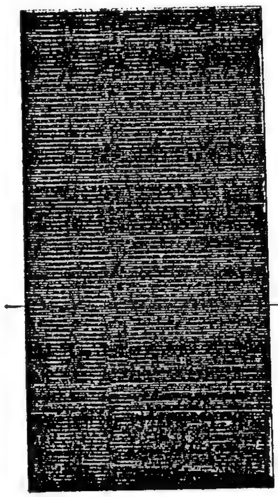
TEST TYPE _____

CYCLIC LOAD _____

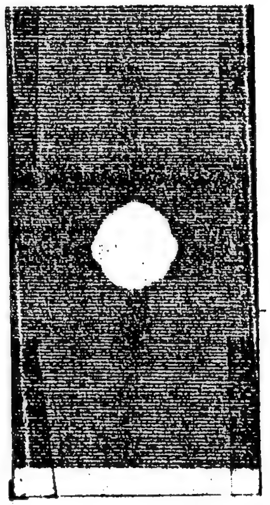
R RATIO _____

TEST TEMPERATURE _____

ULTRASONIC C-SCAN DATA



BEFORE TEST



~~AFTER PRELOAD~~
AFTER IMPACT

MAXIMUM LOAD 30 IN-LB

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

LAMINATE _____

SPECIMEN NO. L1-31A-4

DEFECT _____

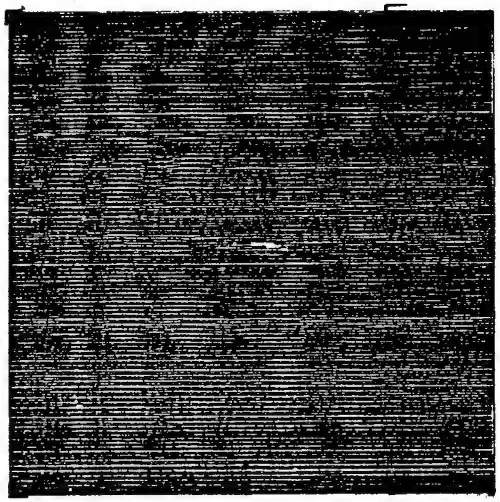
TEST TYPE _____

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

ULTRASONIC C-SCAN DATA



BEFORE TEST

No PRELOAD

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

______ CYCLES

______ CYCLES

MAXIMUM LOAD ______

CYCLIC LOAD ______

R RATIO ______

TEST TEMPERATURE ______

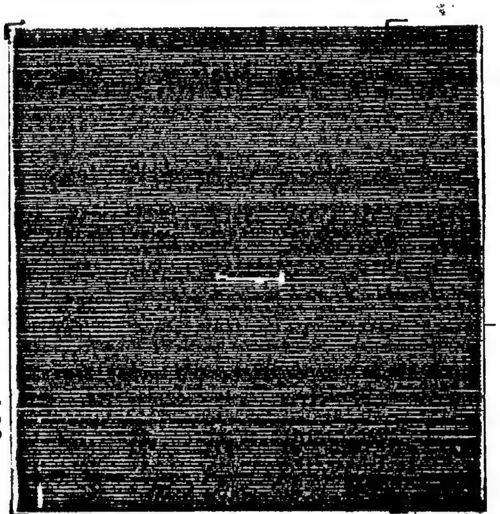
LAMINATE ______

SPECIMEN NO. L1-31A - 5

DEFECT ______

TEST TYPE ______

ULTRASONIC C-SCAN DATA



NO PRELOAD

BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

MAXIMUM LOAD _____

LAMINATE _____

SPECIMEN NO. LI-31A-6

DEFECT _____

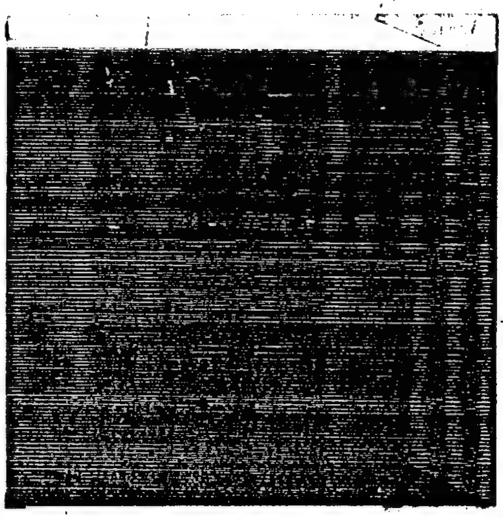
TEST TYPE _____

CYCLIC LOAD _____

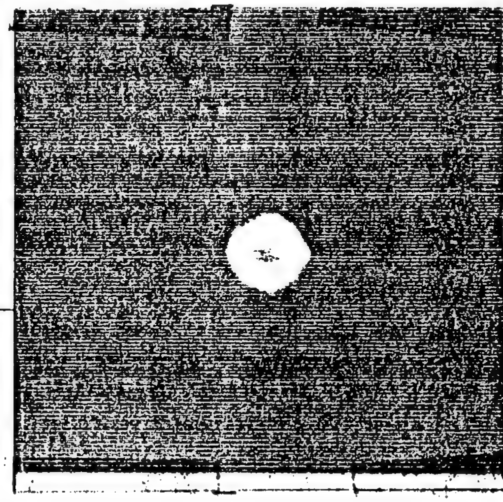
R RATIO _____

TEST TEMPERATURE _____

ULTRASONIC C-SCAN DATA



BEFORE TEST



~~AFTER PRELOAD~~

~~AFTER MOISTURE CONDITIONING~~
AFTER IMPACT

_____ CYCLES

_____ CYCLES

MAXIMUM LOAD _____ 30 IN-LB

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

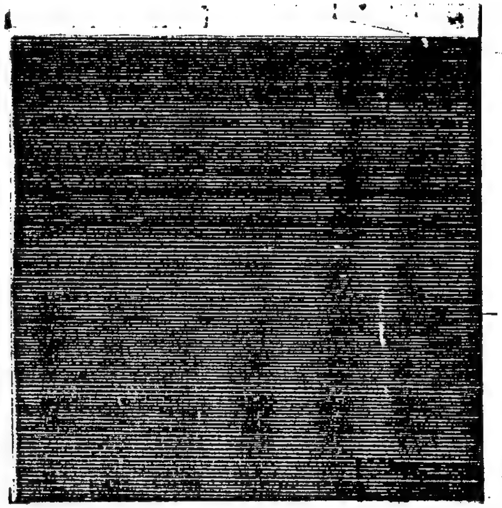
LAMINATE _____

SPECIMEN NO. LI-31A-7

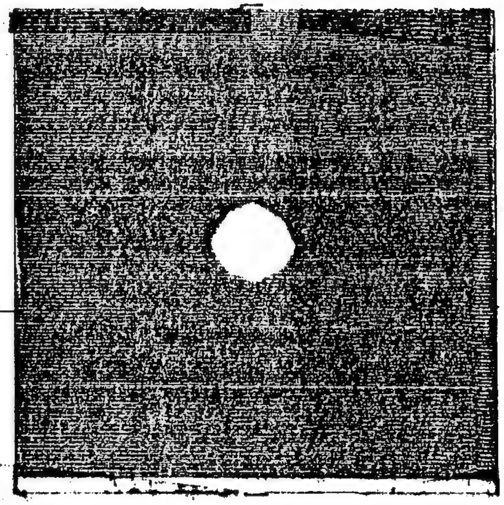
DEFECT _____

TEST TYPE _____

ULTRASONIC C-SCAN DATA



BEFORE TEST



~~AFTER PRELOAD~~

~~AFTER MOISTURE CONDITIONING~~ AFTER IMPACT

_____ CYCLES

_____ CYCLES

~~MAXIMUM LOAD~~ 30 - IN-LB

LAMINATE _____

SPECIMEN NO. L1-31A-8

DEFECT _____

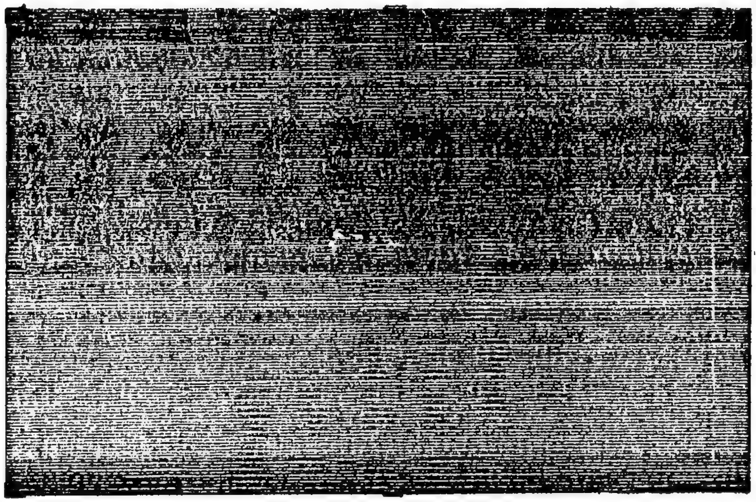
TEST TYPE _____

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | ______ CYCLES | ______ CYCLES

MAXIMUM LOAD ________

CYCLIC LOAD ________

R RATIO ________

TEST TEMPERATURE ________

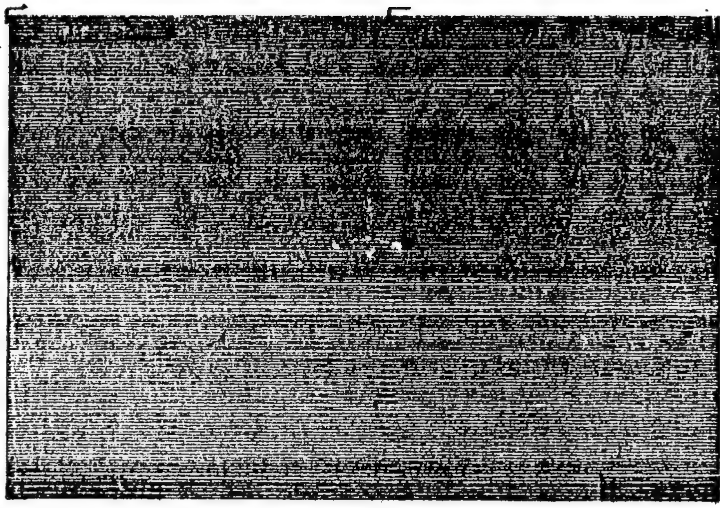
LAMINATE ________

SPECIMEN NO. L1-31A -9

DEFECT ________

TEST TYPE ________

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

MAXIMUM LOAD _____

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

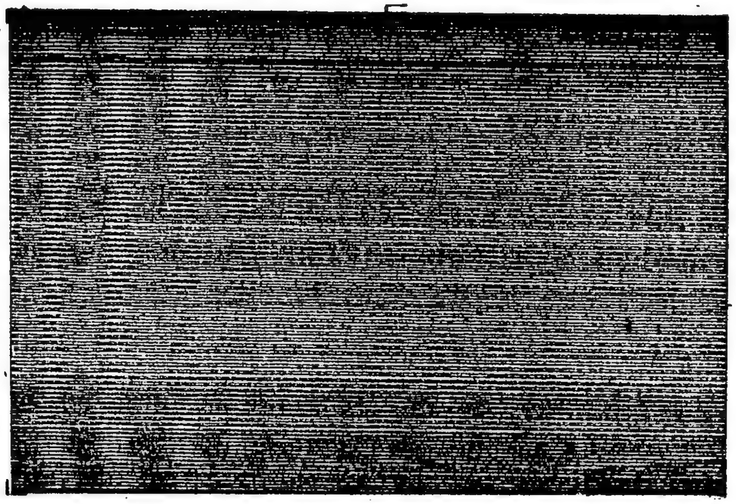
LAMINATE _____

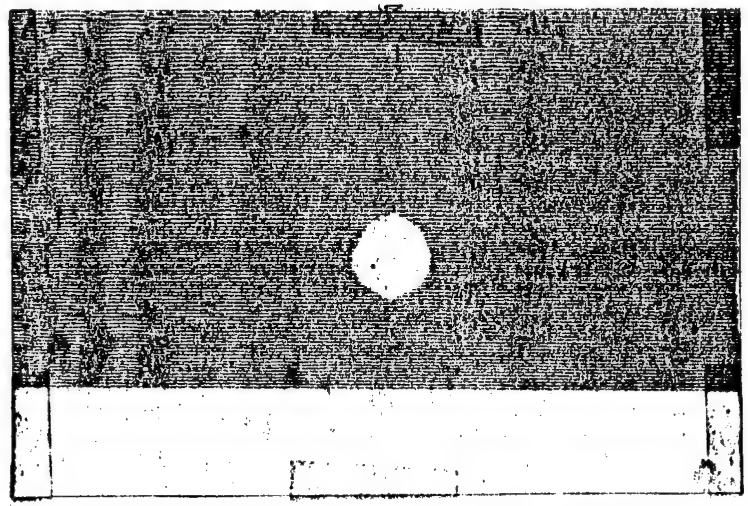
SPECIMEN NO. LI-31A-10

DEFECT _____

TEST TYPE _____

ULTRASONIC C-SCAN DATA





BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

MAXIMUM LOAD _____

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

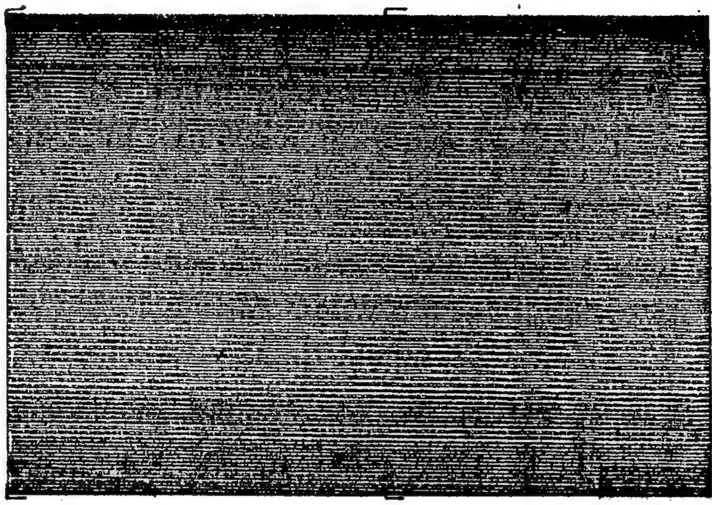
LAMINATE _____

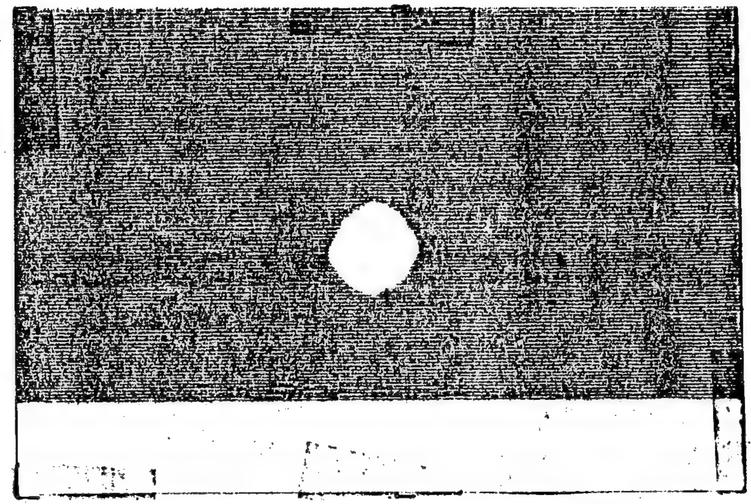
SPECIMEN NO. L1-31A-11

DEFECT _____

TEST TYPE _____

ULTRASONIC C-SCAN DATA





BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

______ CYCLES

______ CYCLES

MAXIMUM LOAD ______

CYCLIC LOAD ______

R RATIO ______

TEST TEMPERATURE ______

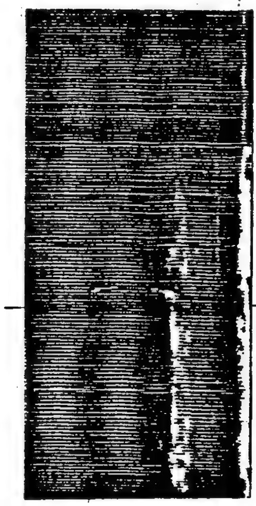
LAMINATE ______

SPECIMEN NO. L1-31A-12

DEFECT ______

TEST TYPE ______

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

MAXIMUM LOAD _____

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

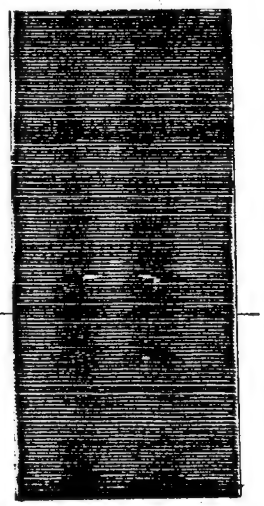
LAMINATE _____

SPECIMEN NO. L3-31-13

DEFECT _____

TEST TYPE _____

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_______ CYCLES

_______ CYCLES

MAXIMUM LOAD __________

CYCLIC LOAD __________

R RATIO __________

TEST TEMPERATURE __________

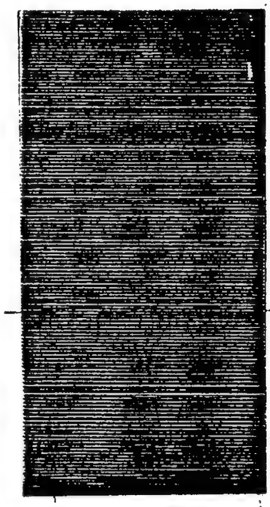
LAMINATE __________

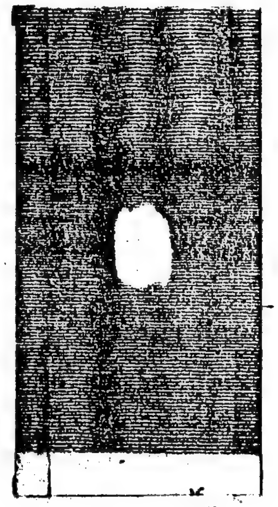
SPECIMEN NO. L3-31-14

DEFECT __________

TEST TYPE __________

ULTRASONIC C-SCAN DATA





BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

______ CYCLES

______ CYCLES

MAXIMUM LOAD ______

CYCLIC LOAD ______

R RATIO ______

TEST TEMPERATURE ______

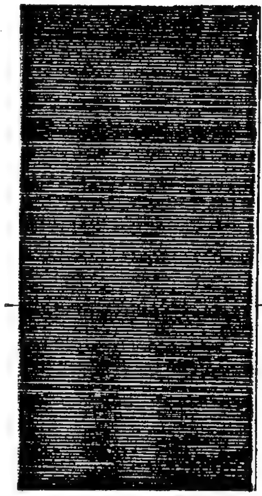
LAMINATE ______

SPECIMEN NO. L3-31-15

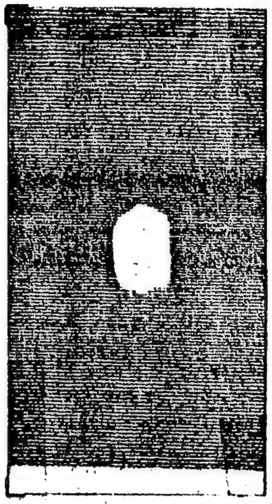
DEFECT ______

TEST TYPE ______

ULTRASONIC C-SCAN DATA



BEFORE TEST



AFTER PRELOAD

AFTER MOISTURE CONDITIONING

______ CYCLES

______ CYCLES

MAXIMUM LOAD ________

CYCLIC LOAD ________

R RATIO ________

TEST TEMPERATURE ________

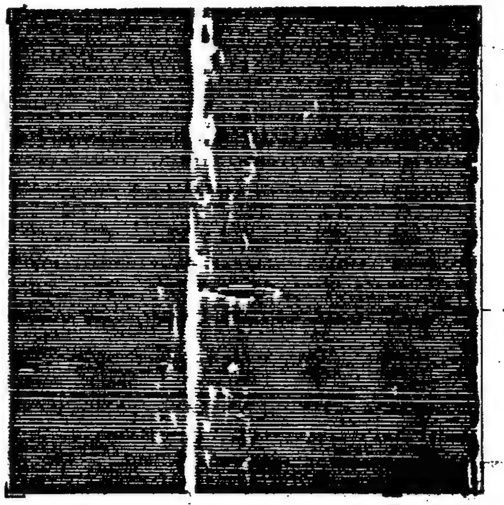
LAMINATE ________

SPECIMEN NO. L3-31-16

DEFECT ________

TEST TYPE ________

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_______ CYCLES

_______ CYCLES

MAXIMUM LOAD _______

CYCLIC LOAD _______

R RATIO _______

TEST TEMPERATURE _______

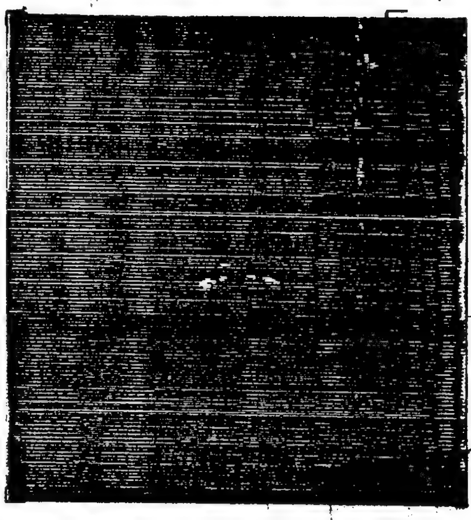
LAMINATE _______

SPECIMEN NO. L3-31-17

DEFECT _______

TEST TYPE _______

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

______ CYCLES

______ CYCLES

MAXIMUM LOAD ________

CYCLIC LOAD ________

R RATIO ________

TEST TEMPERATURE ________

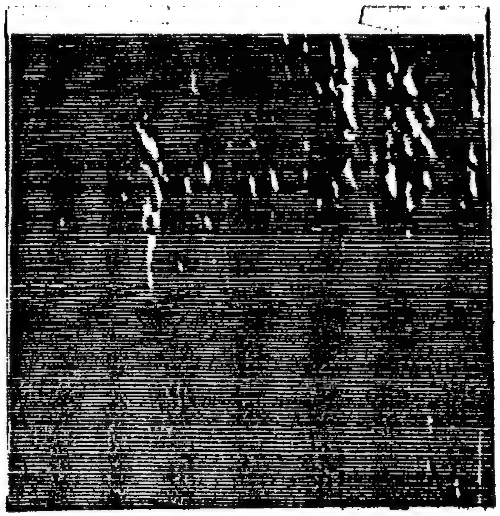
LAMINATE ________

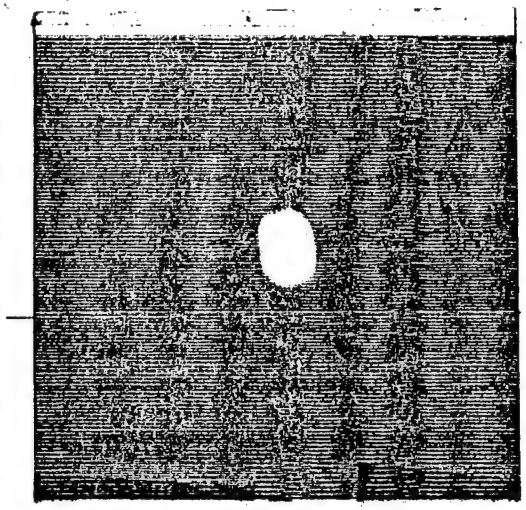
SPECIMEN NO. L3-31-18

DEFECT ________

TEST TYPE ________

ULTRASONIC C-SCAN DATA





BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_______ CYCLES

_______ CYCLES

MAXIMUM LOAD ________

CYCLIC LOAD ________

R RATIO ________

TEST TEMPERATURE ________

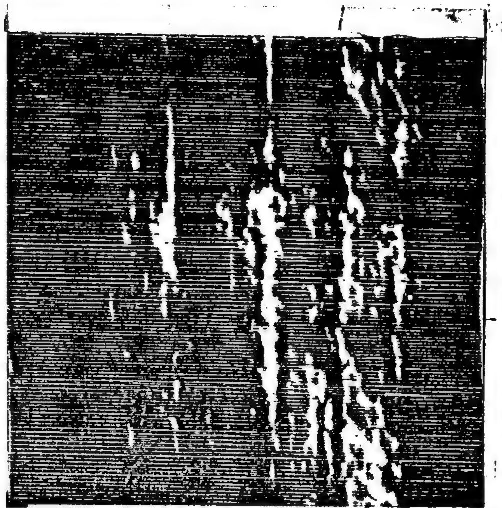
LAMINATE ________

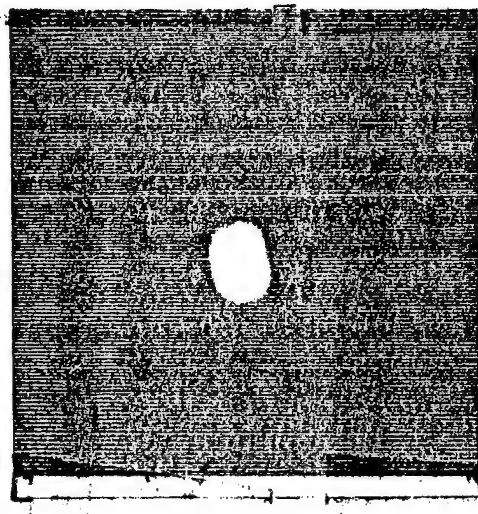
SPECIMEN NO. L3-31-19

DEFECT ________

TEST TYPE ________

ULTRASONIC C-SCAN DATA





BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | ______ CYCLES | ______ CYCLES

MAXIMUM LOAD ______

LAMINATE ______

SPECIMEN NO. L3-31-20

DEFECT ______

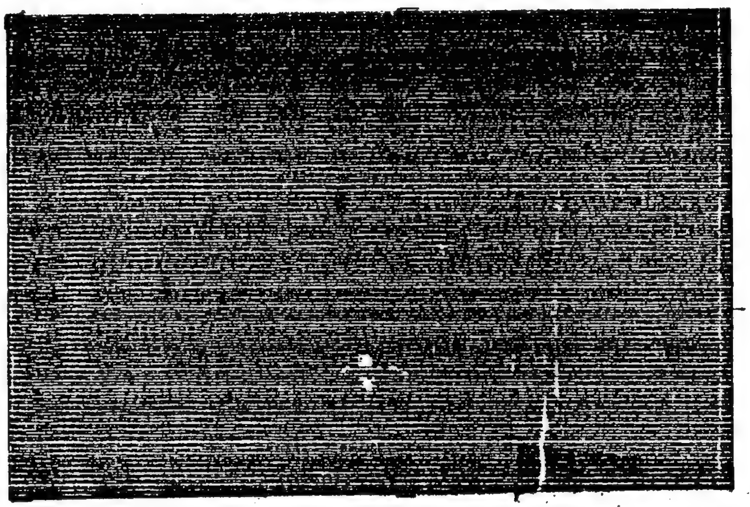
TEST TYPE ______

CYCLIC LOAD ______

R RATIO ______

TEST TEMPERATURE ______

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_______ CYCLES

_______ CYCLES

MAXIMUM LOAD _______

CYCLIC LOAD _______

R RATIO _______

TEST TEMPERATURE _______

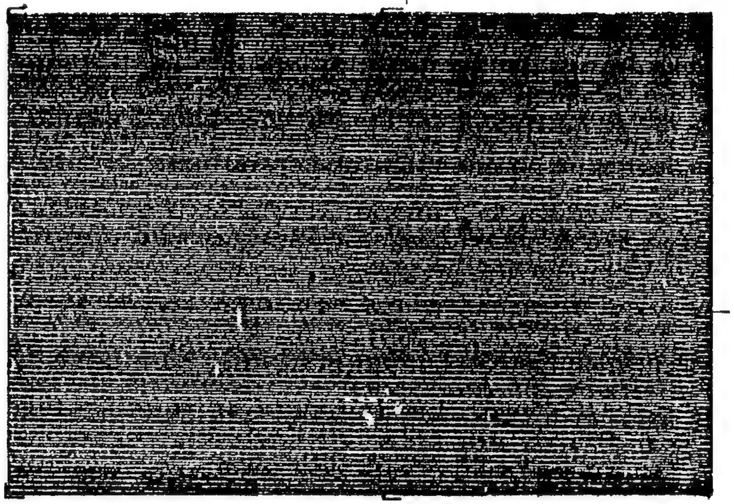
LAMINATE _______

SPECIMEN NO. L3-31-21

DEFECT _______

TEST TYPE _______

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

______ CYCLES

______ CYCLES

MAXIMUM LOAD ______

CYCLIC LOAD ______

R RATIO ______

TEST TEMPERATURE ______

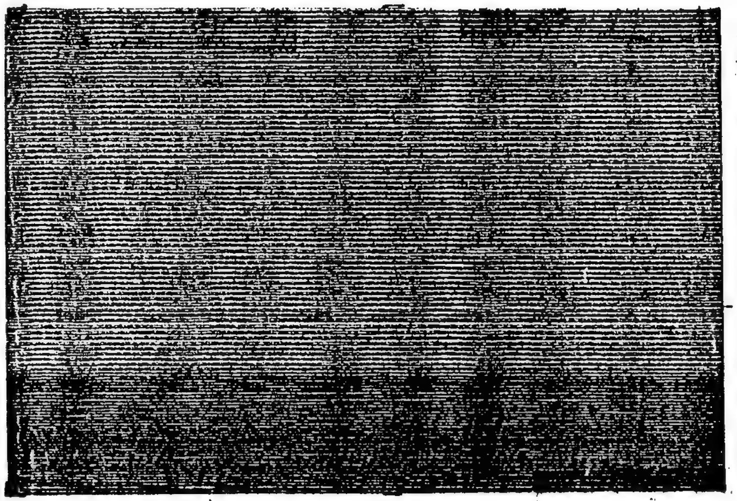
LAMINATE ______

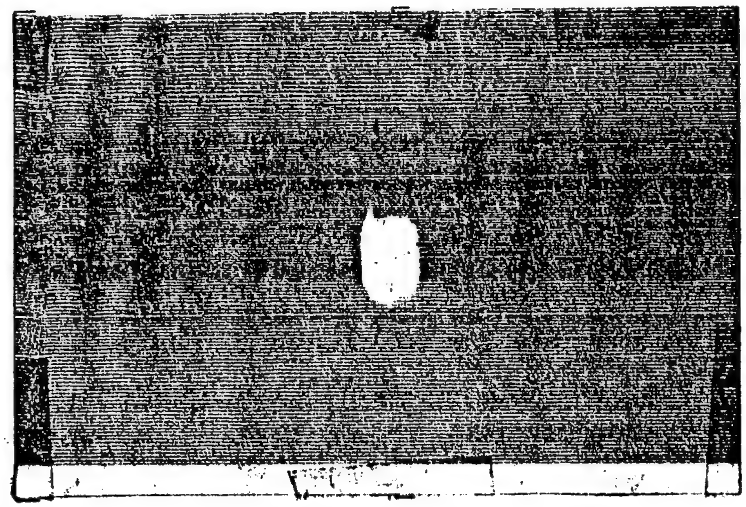
SPECIMEN NO. L3-31-22

DEFECT ______

TEST TYPE ______

ULTRASONIC C-SCAN DATA





BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | ______ CYCLES | ______ CYCLES

MAXIMUM LOAD ______

CYCLIC LOAD ______

R RATIO ______

TEST TEMPERATURE ______

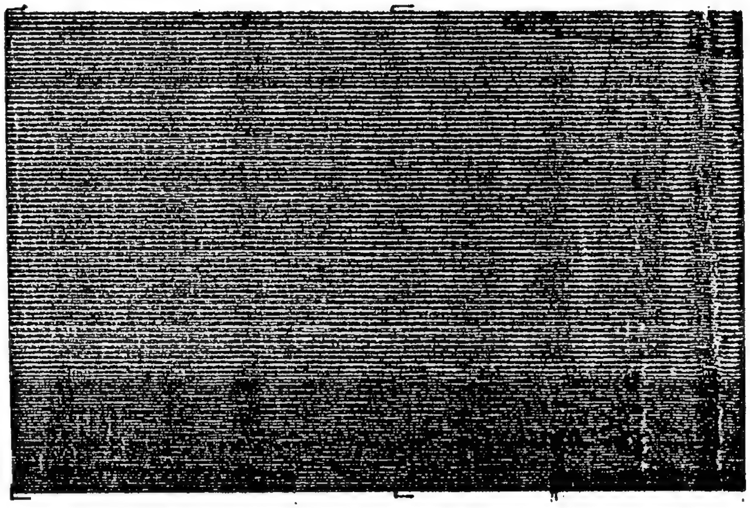
LAMINATE ______

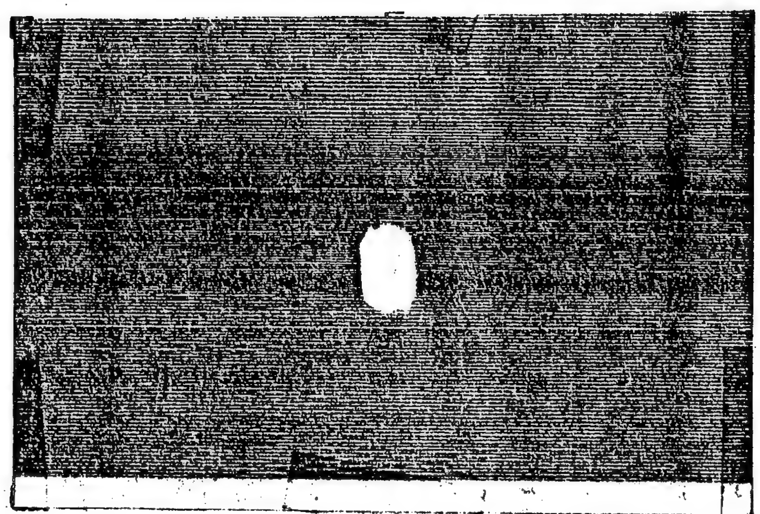
SPECIMEN NO. L3-31-23

DEFECT ______

TEST TYPE ______

ULTRASONIC C-SCAN DATA





BEFORE TEST — AFTER PRELOAD — AFTER MOISTURE CONDITIONING — ______ CYCLES — ______ CYCLES

MAXIMUM LOAD ______

CYCLIC LOAD ______

R RATIO ______

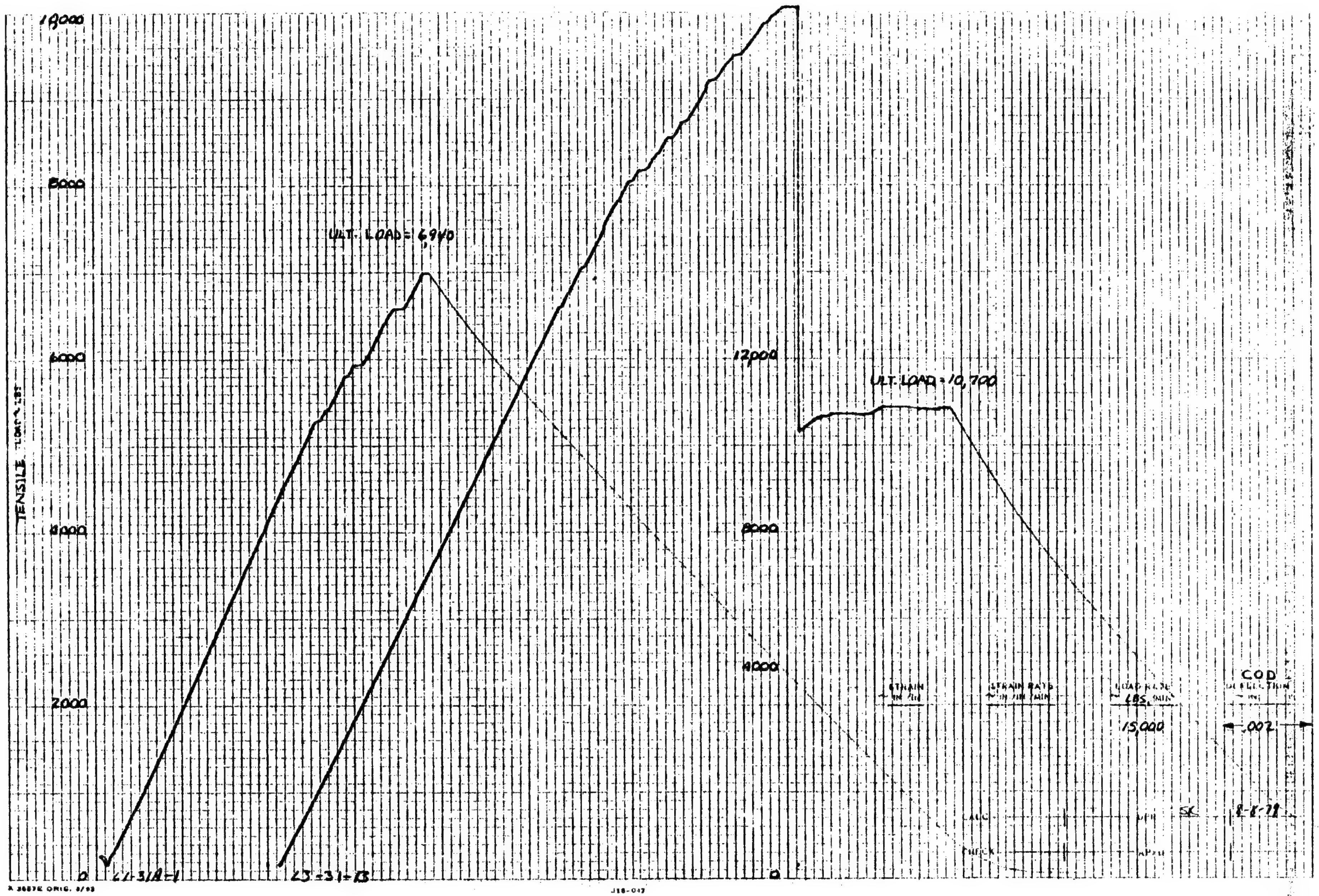
TEST TEMPERATURE ______

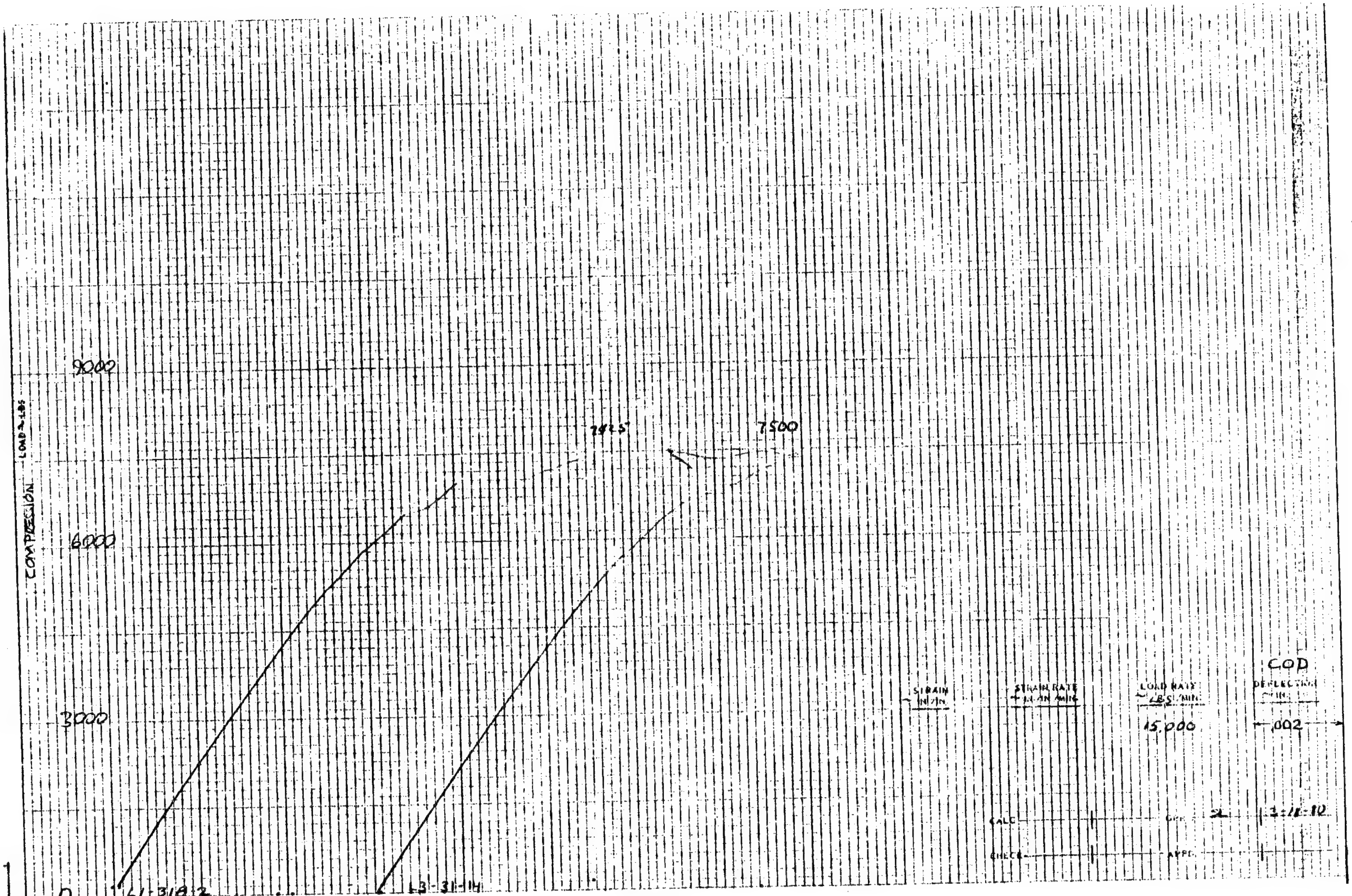
LAMINATE ______

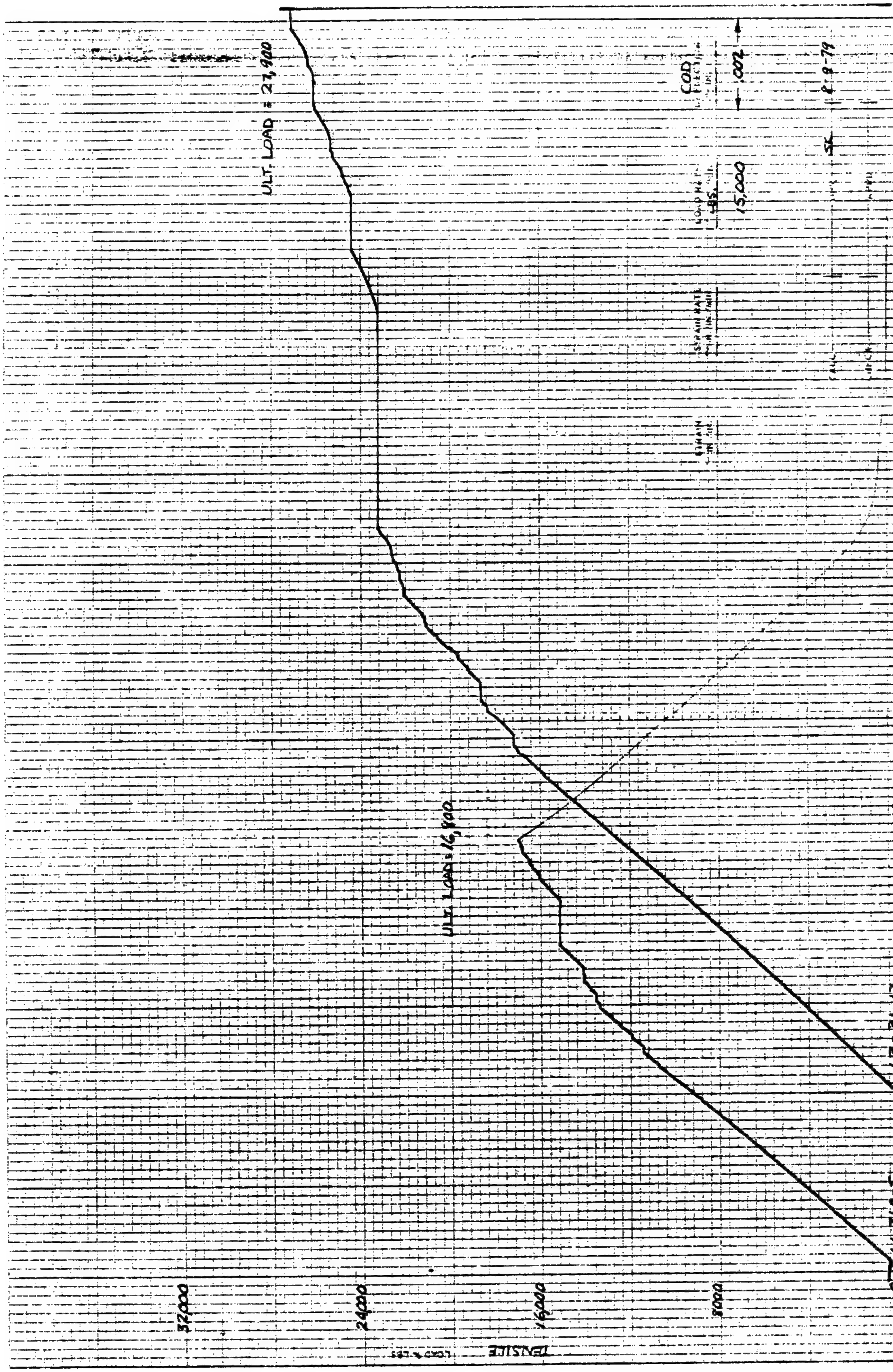
SPECIMEN NO. L3-21-24

DEFECT ______

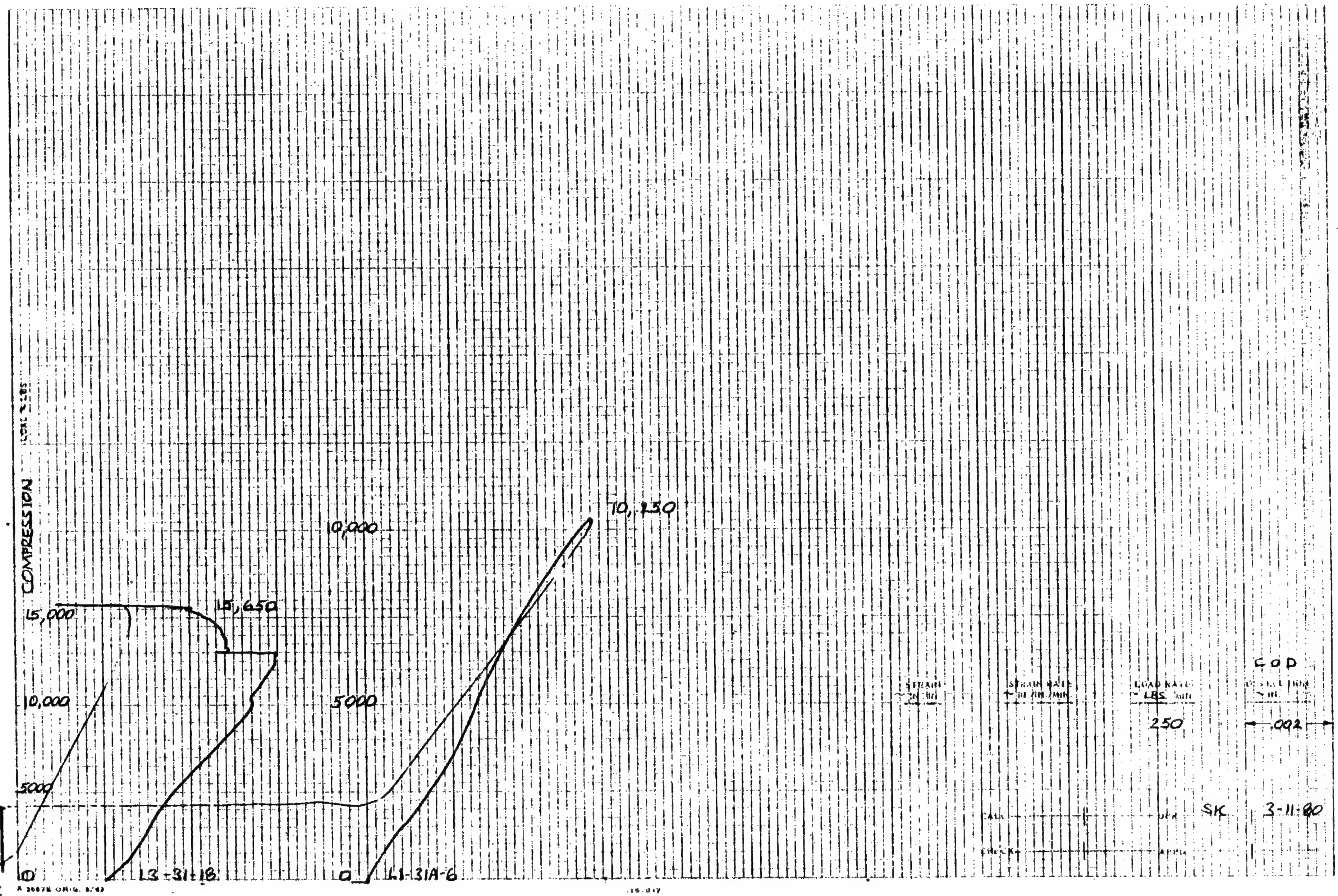
TEST TYPE ______


TENSILE LOAD ~ LBS
18000
8000
6000
4000
2000
0
ULT. LOAD = 6940
ULT. LOAD = 10,700
12000
8000
4000
0
21-31A-1
23-31-13
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS/MIN
15,000
COD DEFLECTION ~ IN
.002
SK
8-8-78

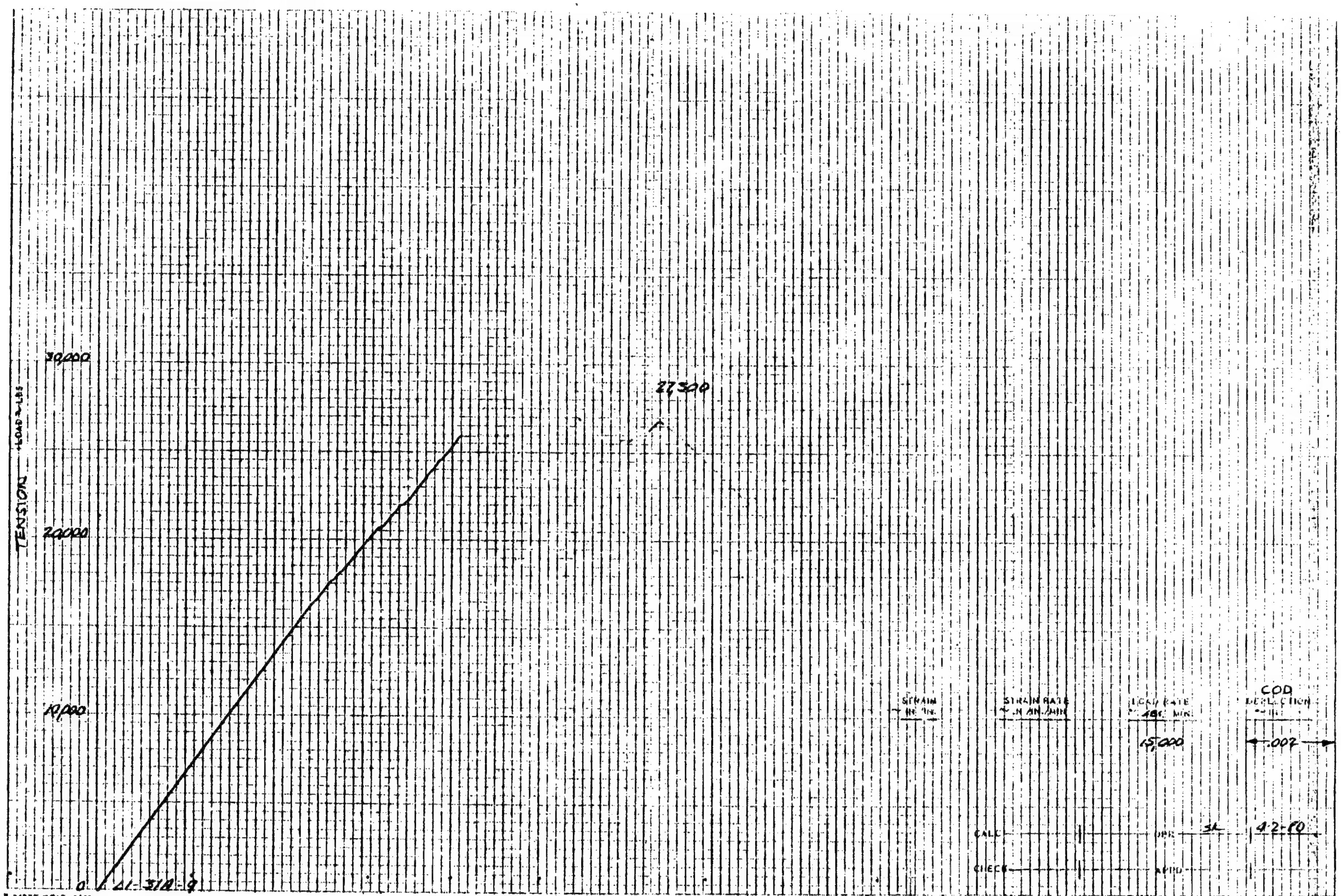

COMPRESSION
LOAD ~ LBS
9000
6000
3000
0
L1-31B-2
L3-31-14
7425
7500
COD
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS/MIN
15,000
DEFLECTION ~ IN
.002
CALC
CHECK
APPD
3-18-70

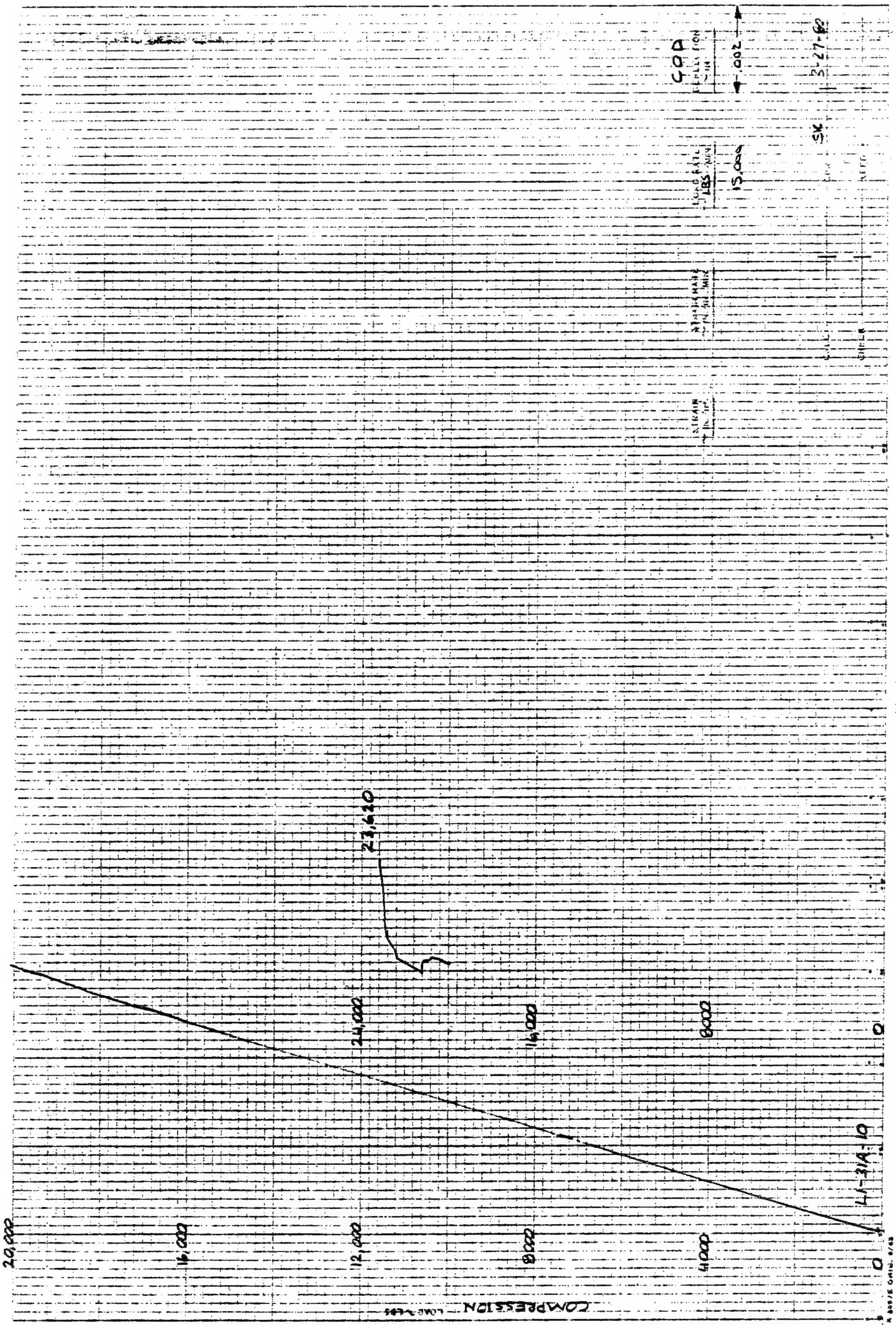


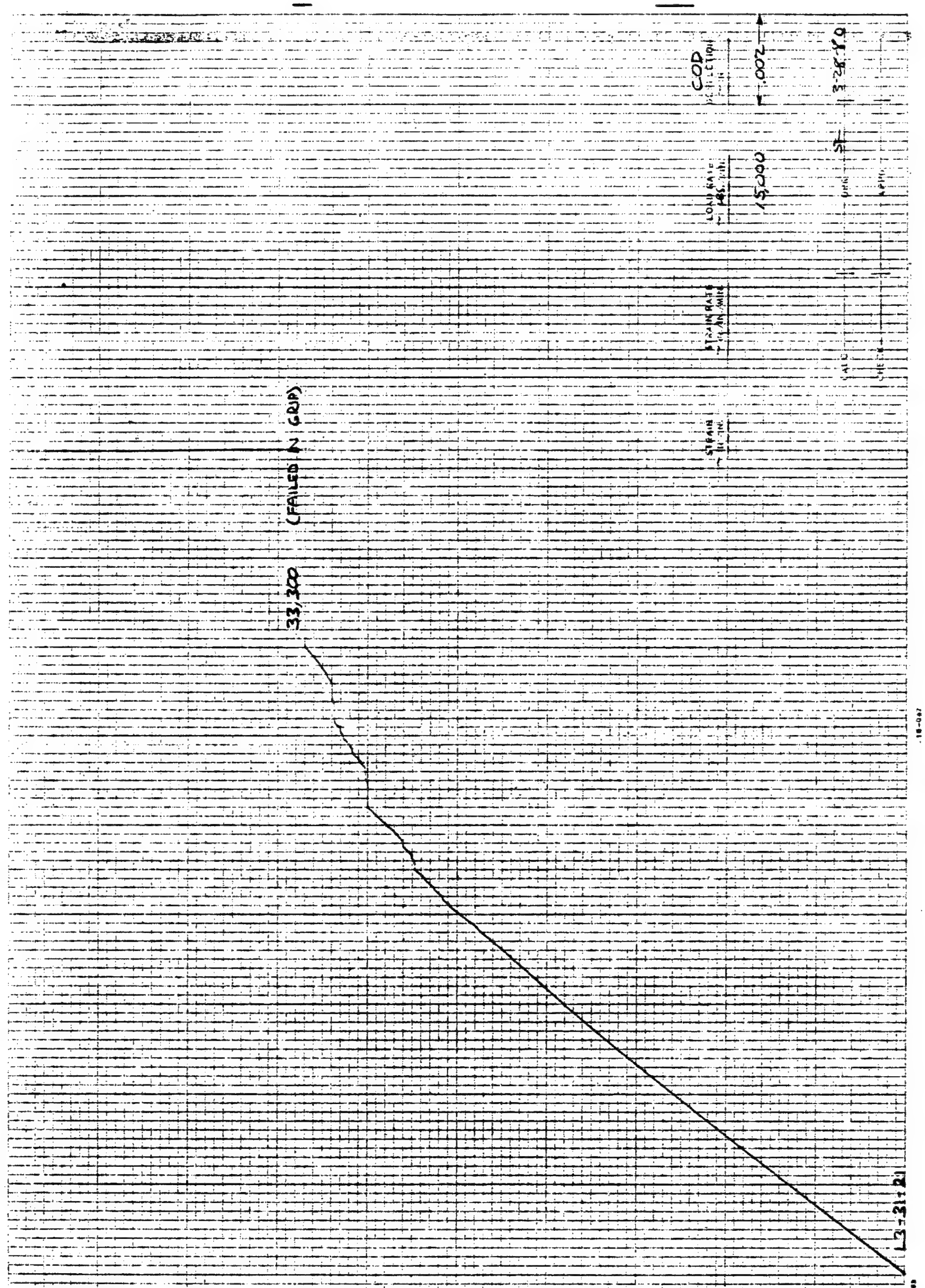
ULT. LOAD = 27,900
ULT. LOAD = 16,800
COD
.002
15,000
2-8-79
SK
32,000
24,000
16,000
8000
0
TENSILE

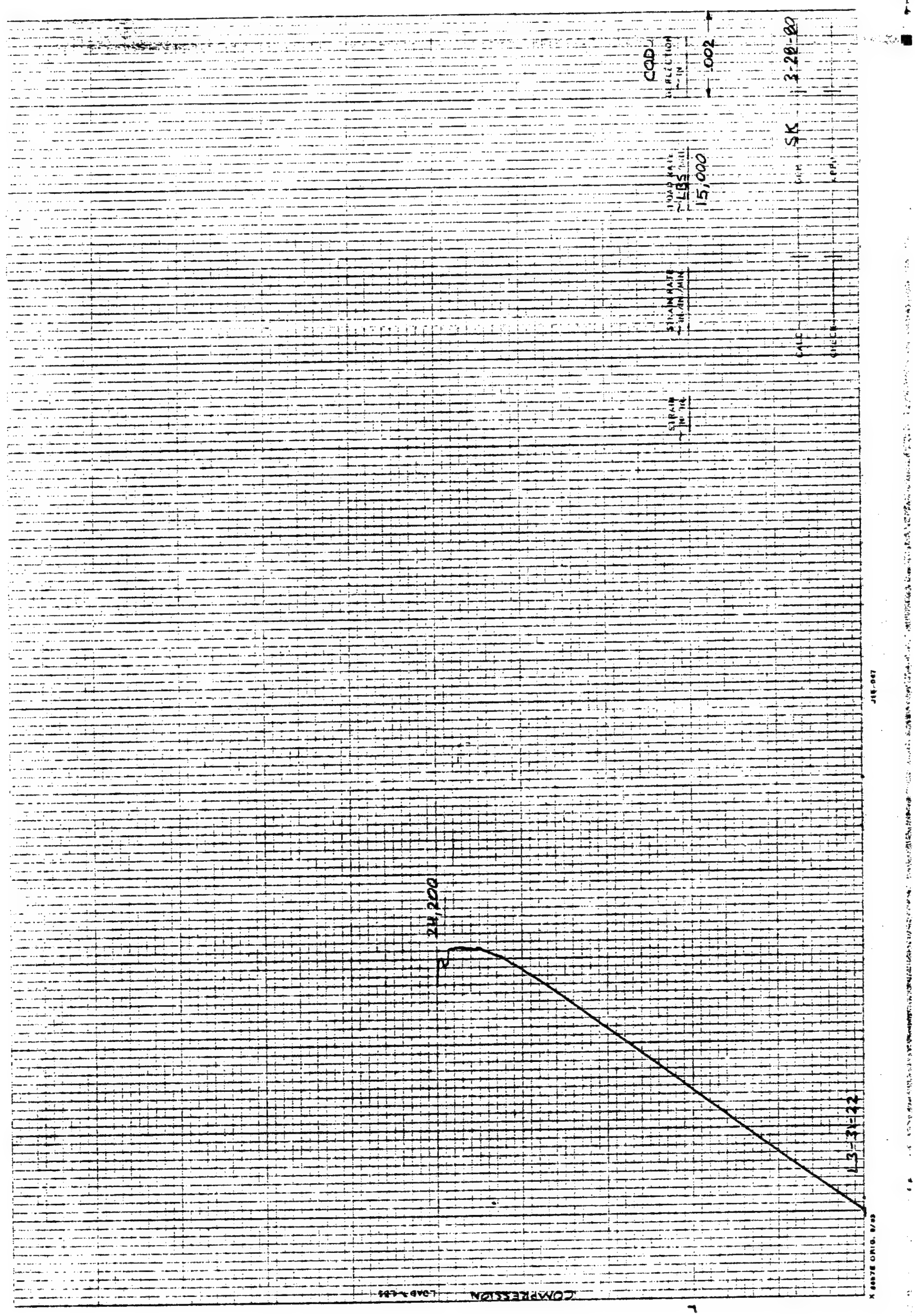


COMPRESSION
LOAD ~ LBS
15,000
10,000
5000
0
15,650
L3-31-1B
10,000
5000
0
L1-31A-6
10,250
COD
LOAD RATE ~ LBS/MIN
250
.002
SK
3-11-80


TENSION
LOAD – LBS
30,000
20,000
10,000
0
27,300
Δ1-31A-9
STRAIN IN./IN.
STRAIN RATE IN./IN./MIN
LOAD RATE LBS/MIN
15,000
COD DEFLECTION
.002
CALC
CHECK
OPR
SL
APPD
4-2-70


COD
.002
15,000
SK
23,620
24,000
16,000
8000
0
20,000
16,000
12,000
8000
4000
0
COMPRESSION


COD
.002
15,000
33,300
(FAILED IN GRIP)
TENSION


COD
DEFLECTION ~IN
.002
LOAD RATE ~LBS
15,000
SK
3-28-80
24,200
L3-31-22
COMPRESSION
LOAD ~ LBS

APPENDIX C

STATIC TEST DAMAGE GROWTH DATA

This appendix contains the crack opening displacement test machine records, the ultrasonic C-scan and the visual notes indicating the damage growth in the static test specimens. The results are grouped according to laminate type and defect. Each record is identified by specimen number and defect code.

All static test specimens were examined using these techniques at each stage in the testing process.

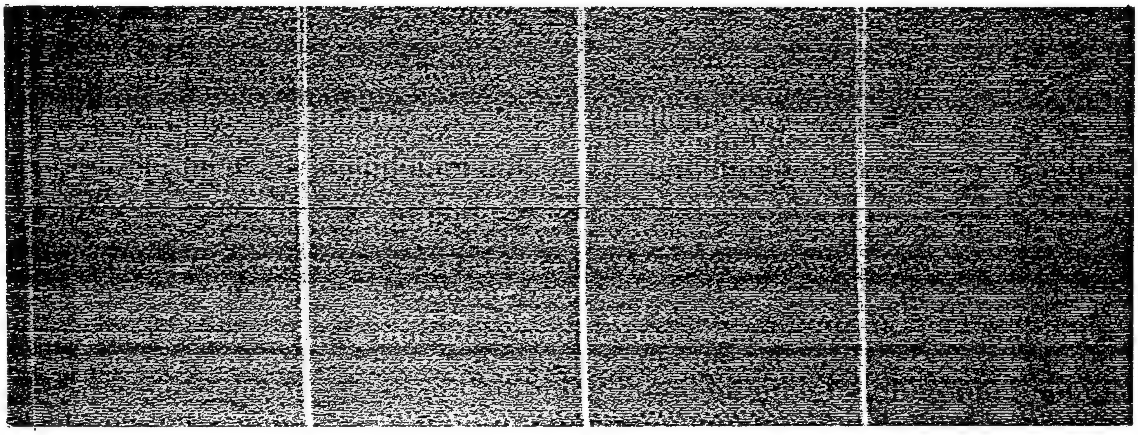
LAMINATE L1

NO DEFECT

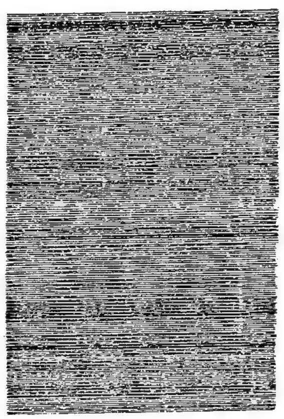
TEST SPECIMENS

ROOM TEMPERATURE		422° K (300° F)	
L1-21-1	L1-21-2	L1-21-3	L1-21-4

INITIAL

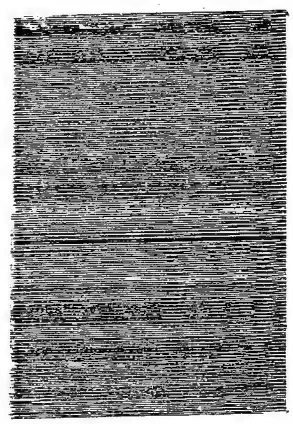


AFTER PRELOAD 21.5 KIP

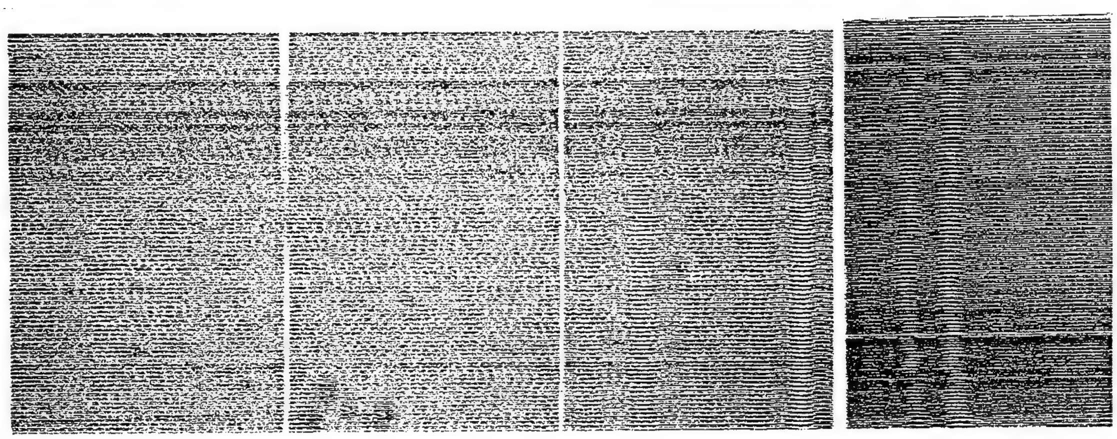


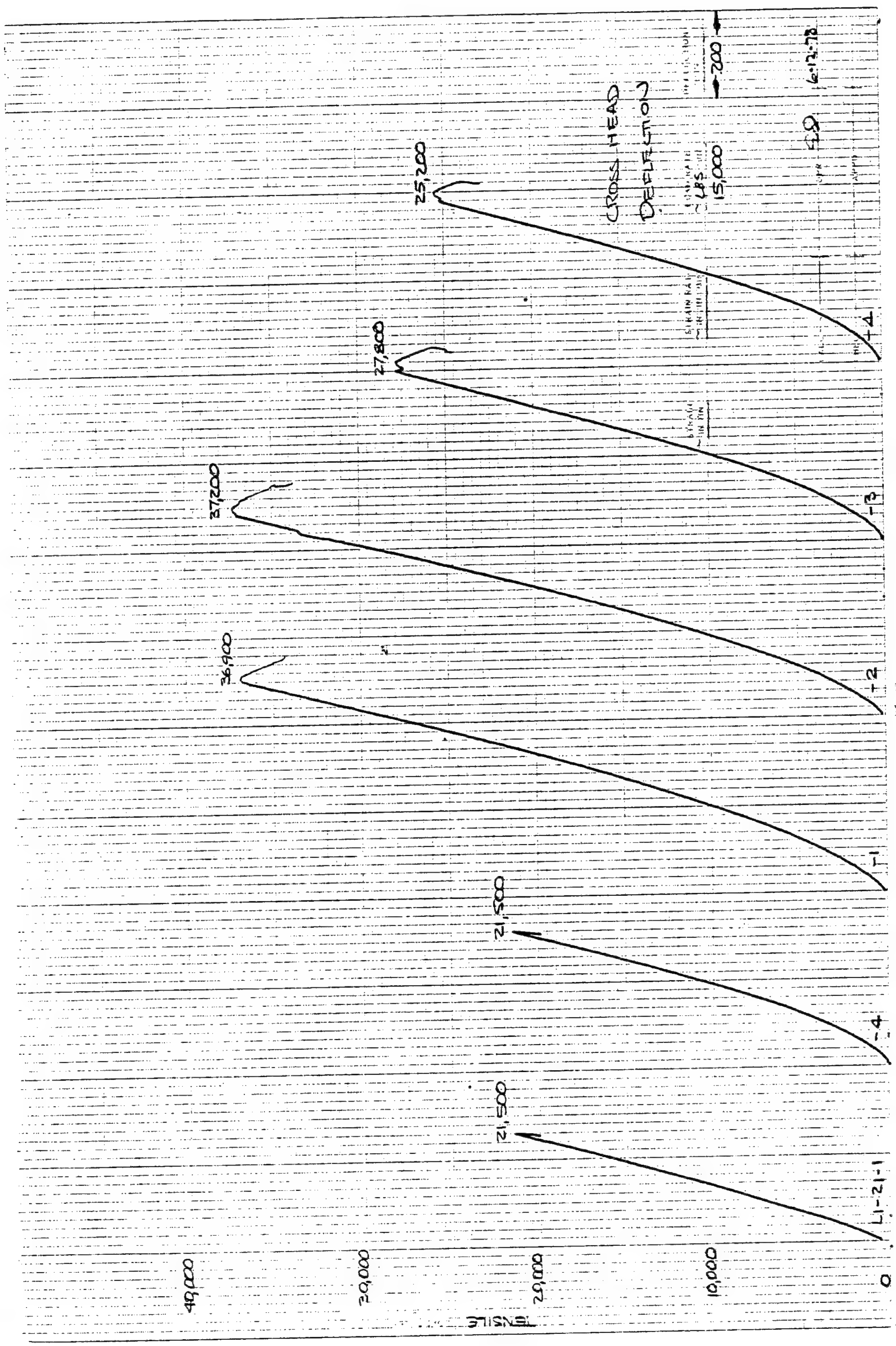
VISUAL DAMAGE

← NONE →



AFTER MOISTURE CONDITIONING





CROSS HEAD
DEFLECTION
LBS
15,000
200
6-12-78
25,200
27,800
37,200
36,900
21,500
21,500
L1-21-1
-1
-2
-3
-4
40,000
30,000
20,000
10,000
0
TENSILE

LAMINATE L1

1/8 FP HOLE

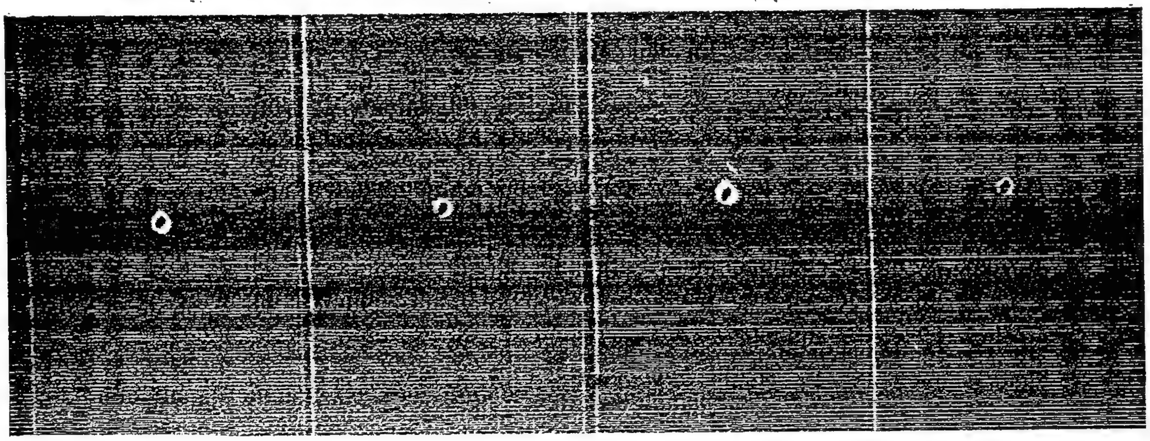
TEST SPECIMENS

ROOM TEMPERATURE

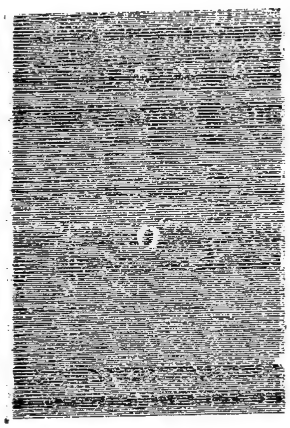
422° K (300° F)

L1-21-5 L1-21-6 L1-21-7 L1-21-8

INITIAL

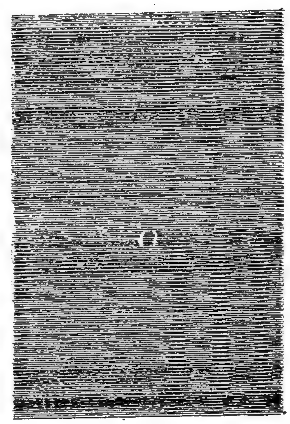


AFTER PRELOAD 15.3 KIP

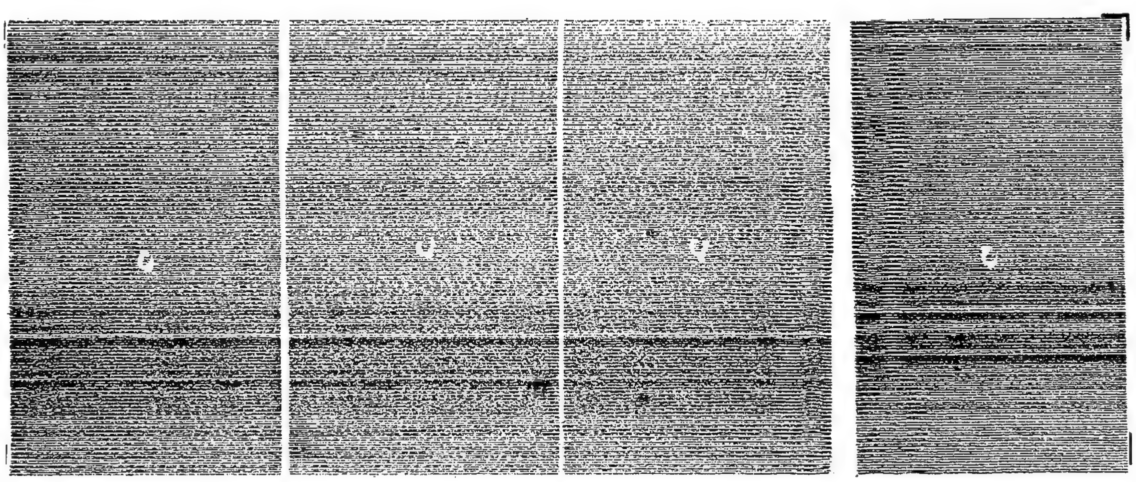


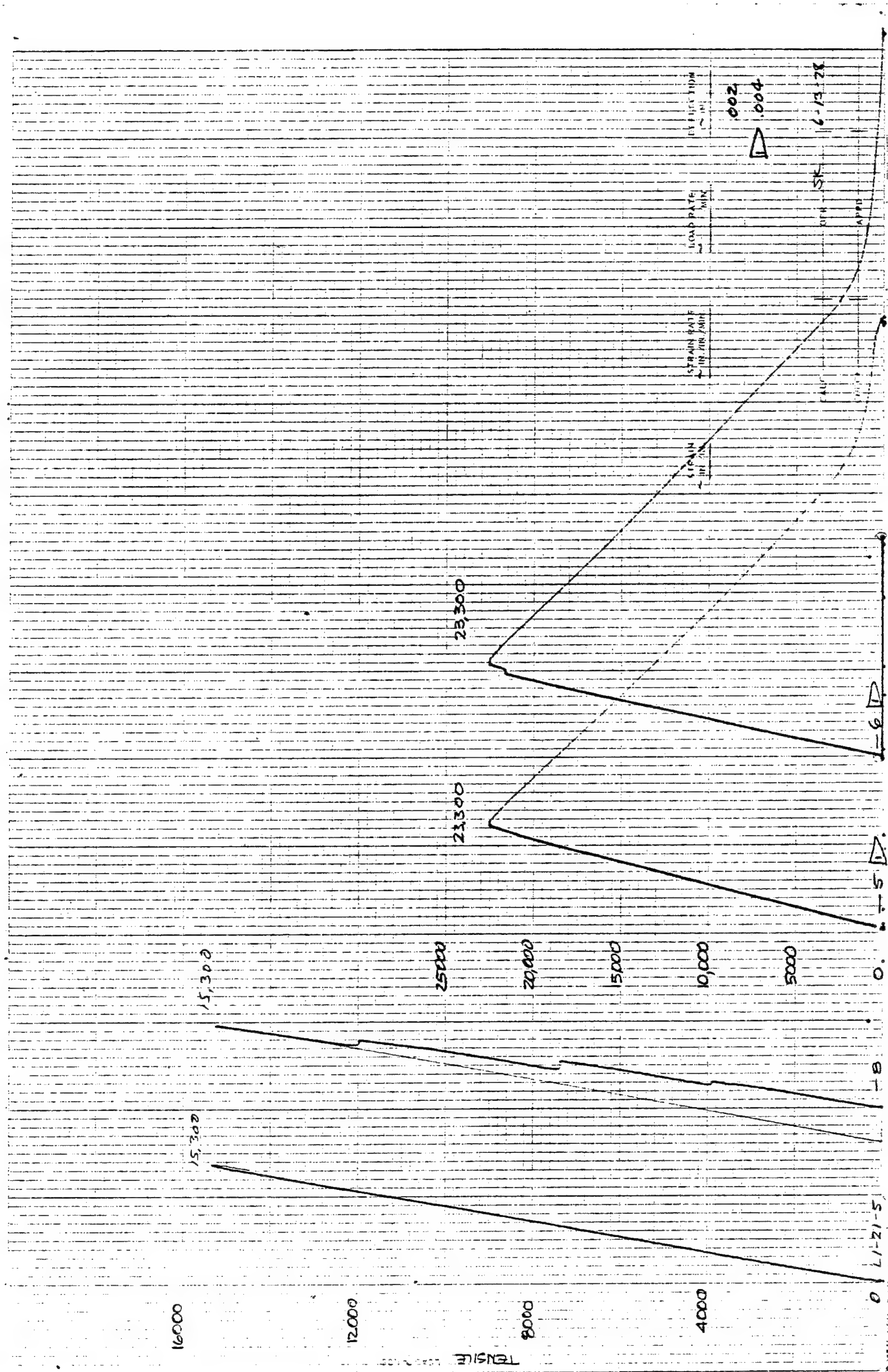
VISUAL DAMAGE

← FINE CRAZE FROM HOLE 0.1 inch IN LENGTH →

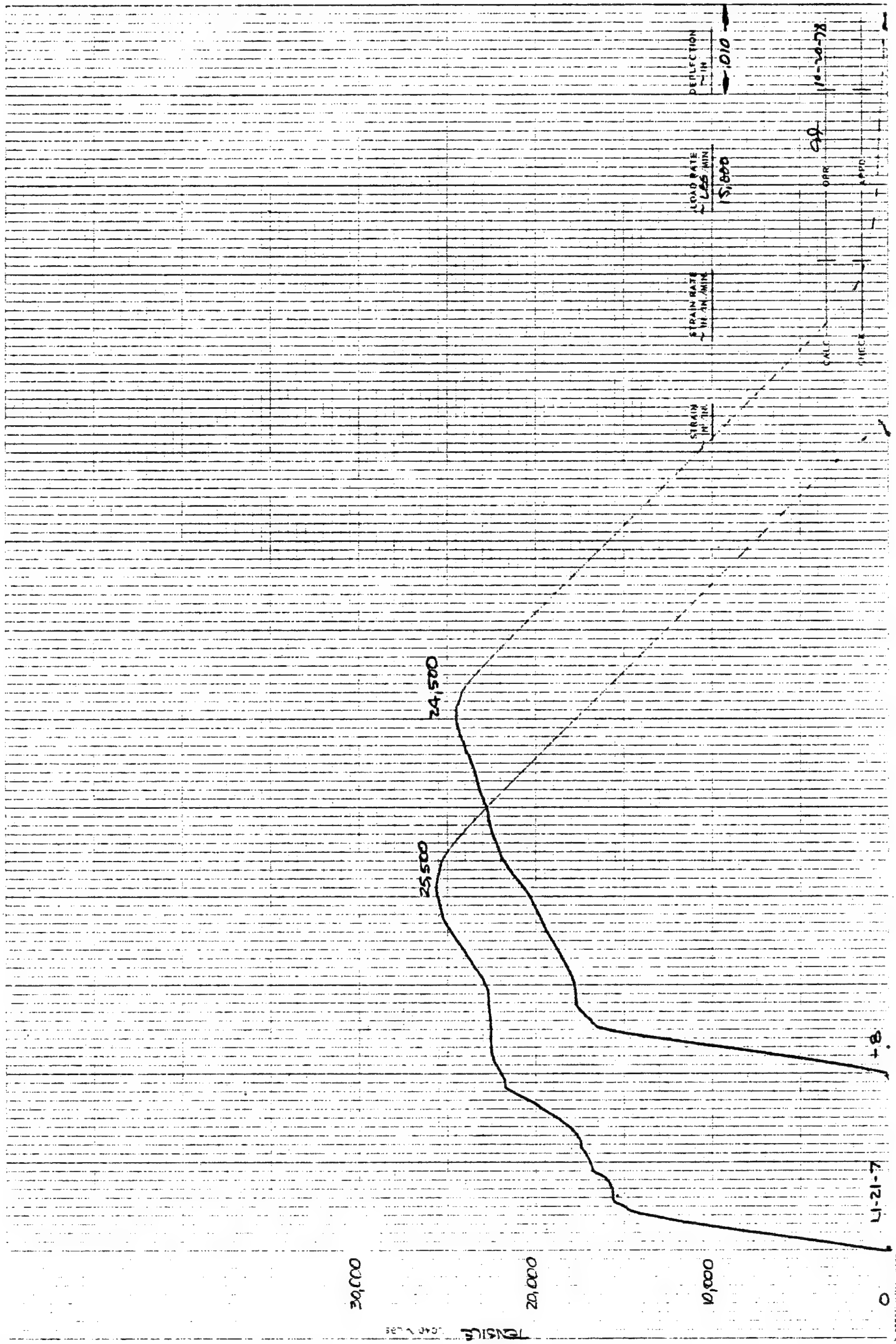


AFTER MOISTURE CONDITIONING





TENSILE
16000
12000
8000
4000
0
L1-21-5
15,300
-8
15,300
25000
20,000
15,000
10,000
5000
0
-5
23,300
-6
23,300
.002
.004
6-13-78



30,000
20,000
10,000
0
TENSILE LOAD ~ LBS
L1-21-7
+8
25,500
24,500
DEFLECTION ~ IN
.010
LOAD RATE ~ LBS/MIN
15,000
STRAIN RATE ~ IN/IN/MIN
STRAIN IN/IN
OPR
CALC
CHECK
APPD
10-26-78

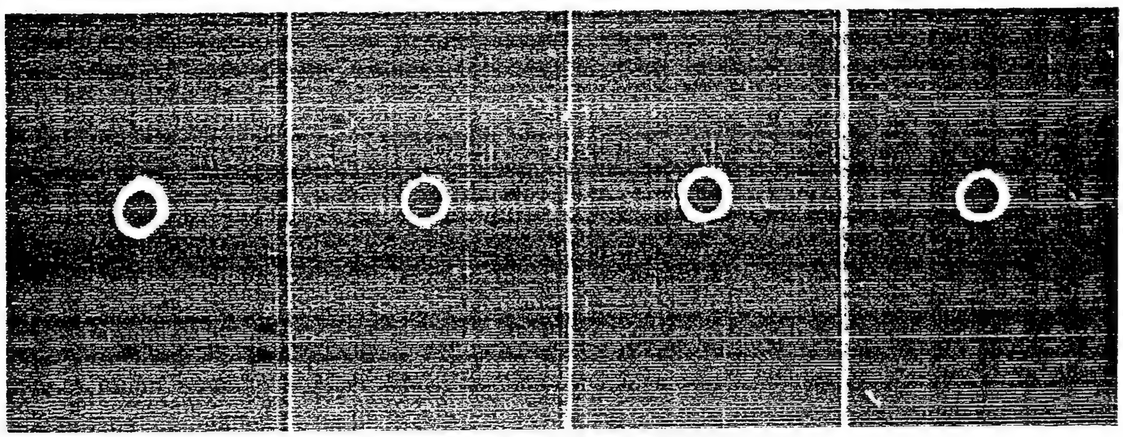
LAMINATE L1

3/8 FP HOLE

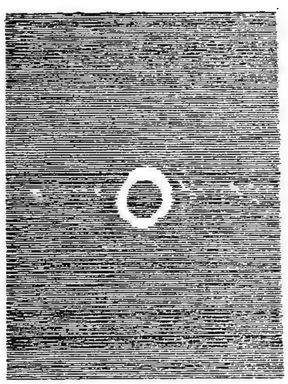
TEST SPECIMENS

ROOM TEMPERATURE		422° K (300° F)	
L1-21-9	L1-21-10	L1-21-11	L1-21-12

INITIAL

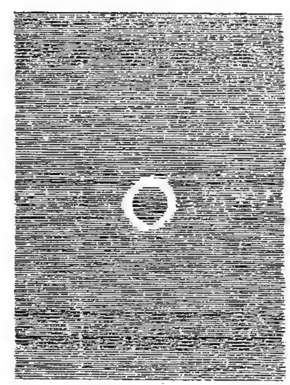


AFTER PRELOAD 11.7 KIP

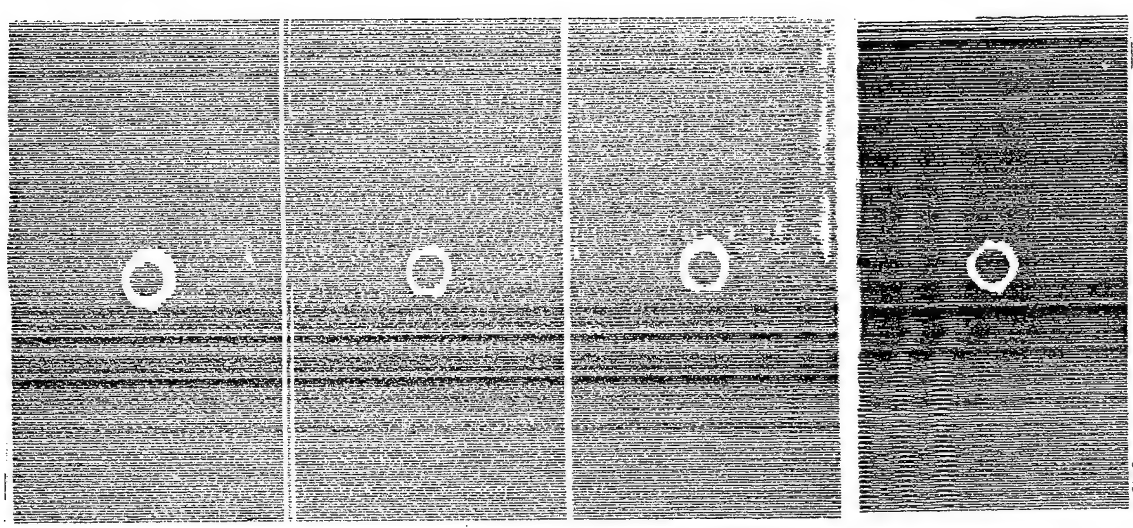


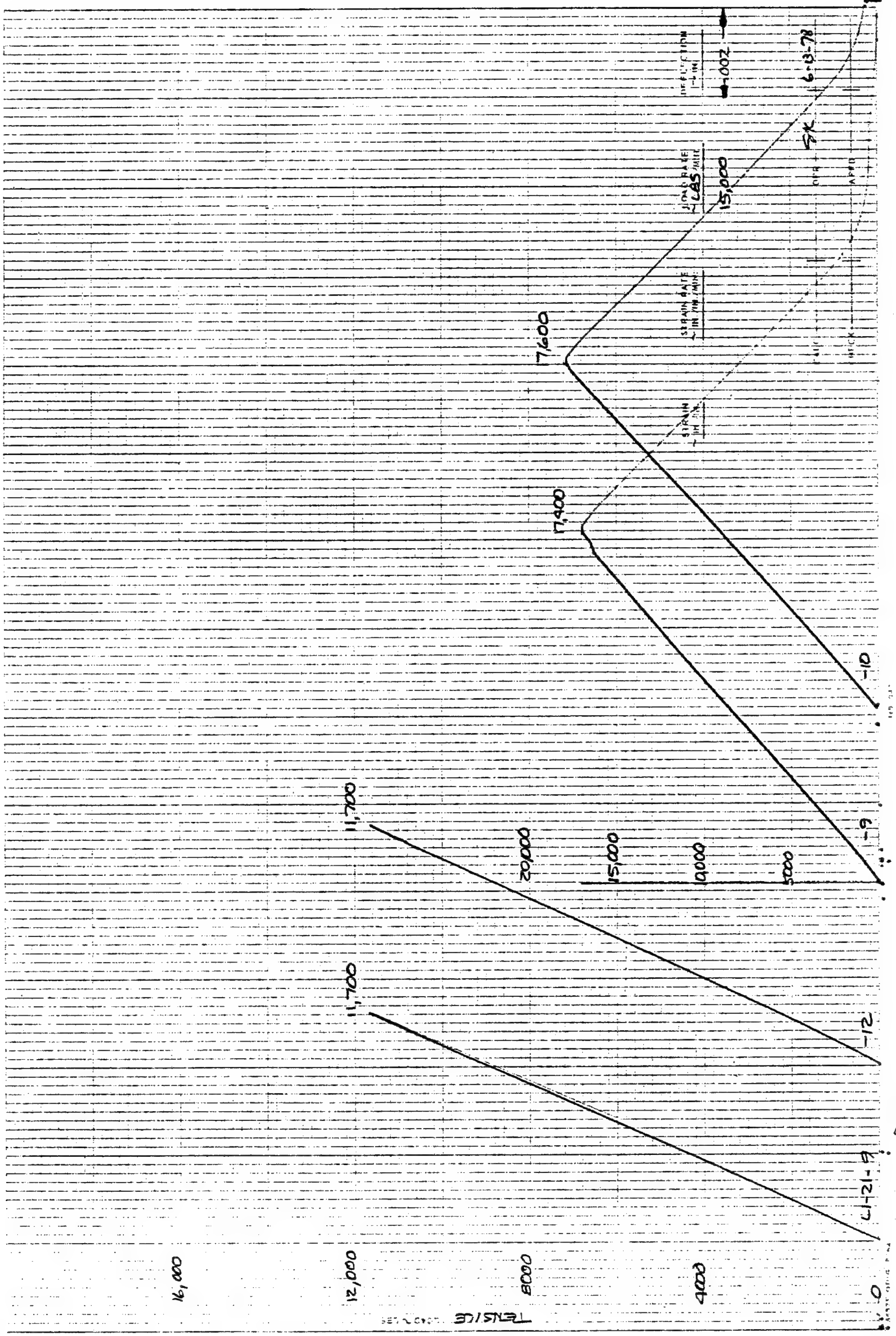
VISUAL DAMAGE

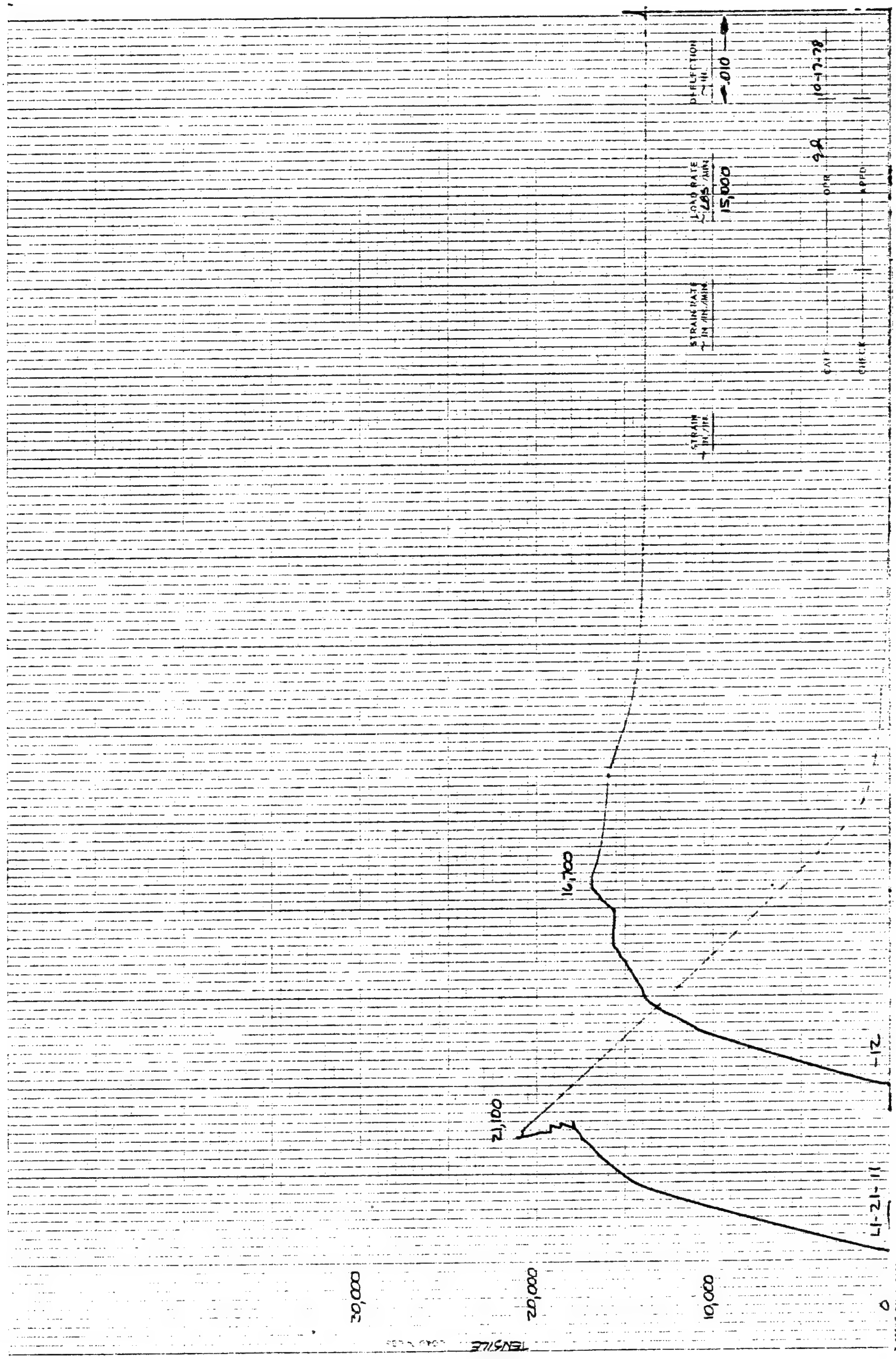
← NONE →



AFTER MOISTURE CONDITIONING




TENSILE
16,000
12,000
8000
4000
0
L1-21-9
-12
11,700
11,700
20,000
15,000
10,000
5000
-9
-10
17,400
17,600
15,000
.002
6-13-78
SK



TENSILE
30,000
20,000
10,000
0
300°
21,100
16,700
L1-21-11
-12
STRAIN
IN./IN.
STRAIN RATE
IN./IN./MIN.
LOAD RATE
LBS/MIN
15,000
DEFLECTION
IN.
.010
CALL
CHECK
OPR
APPD
10-17-78

LAMINATE L1

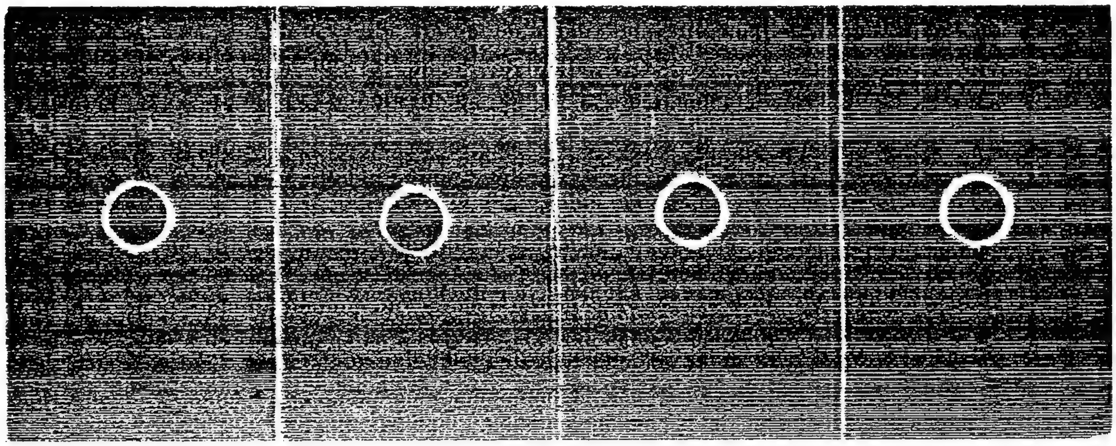
5/8 FP HOLE

TEST SPECIMENS

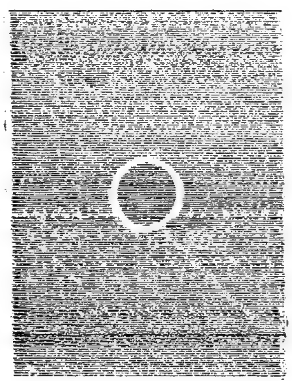
ROOM TEMPERATURE — 422° K (300° F)

L1-21-13	L1-21-14	L1-21-15	L1-21-16

INITIAL

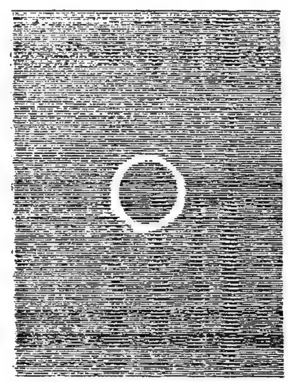


AFTER PRELOAD 10.4 KIP

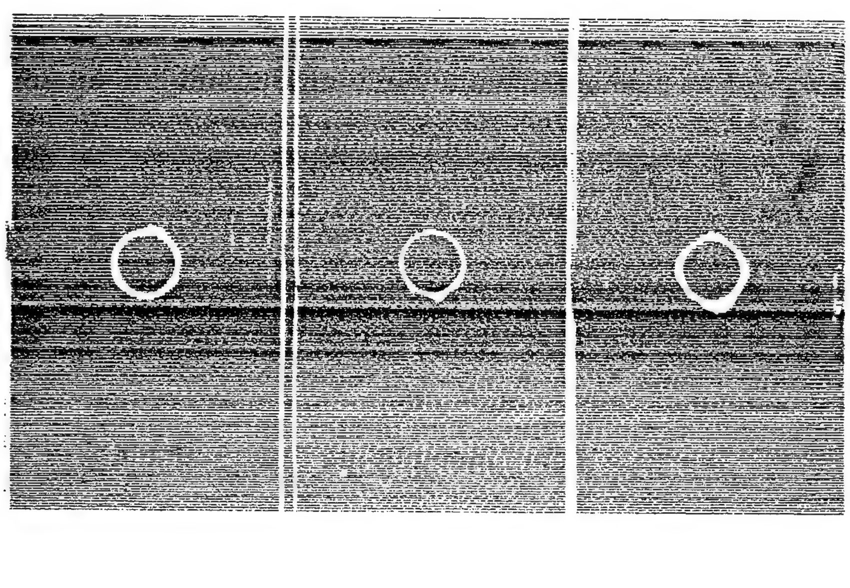


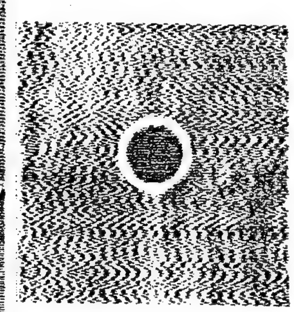
VISUAL DAMAGE

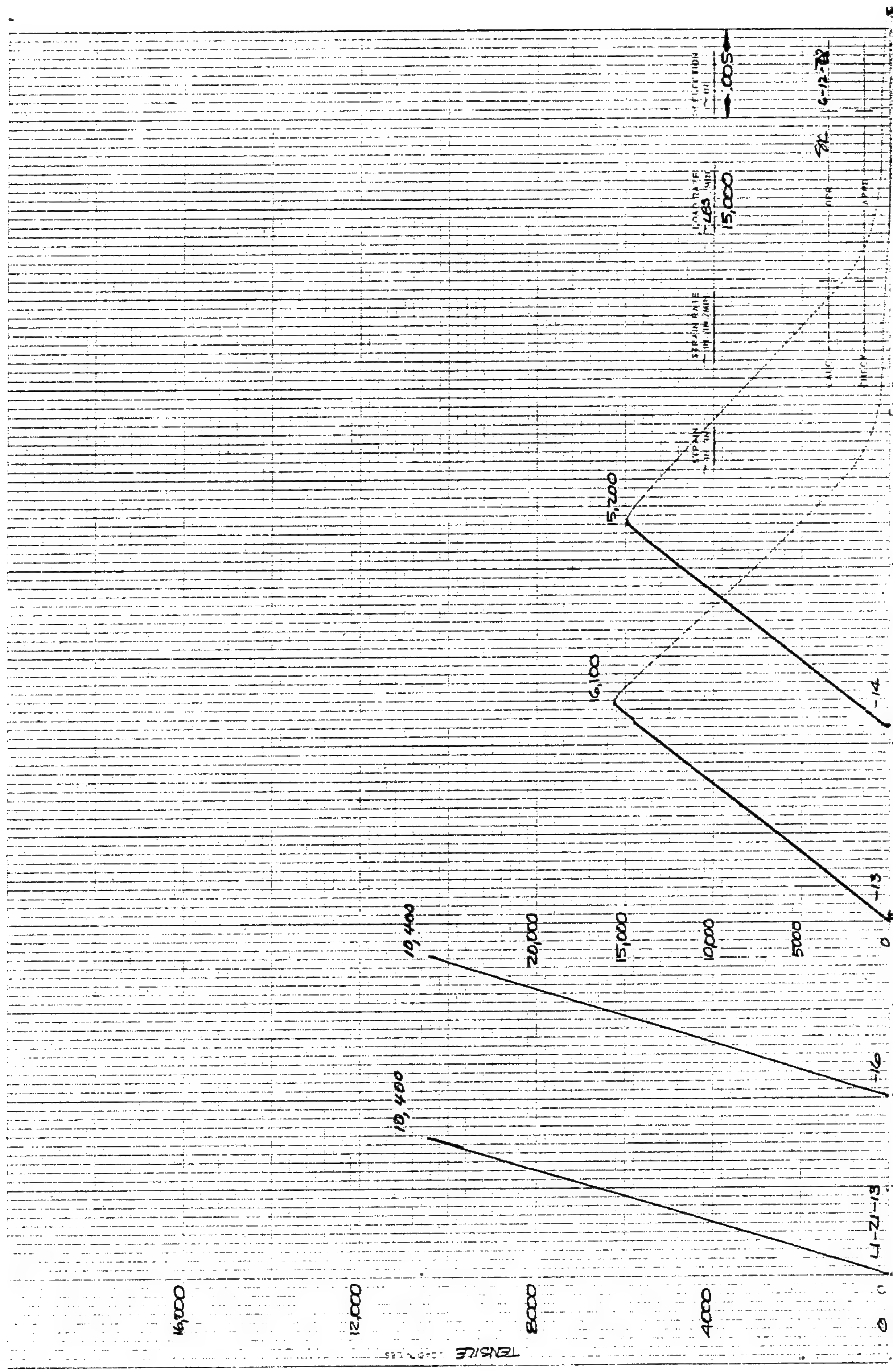
← NONE →



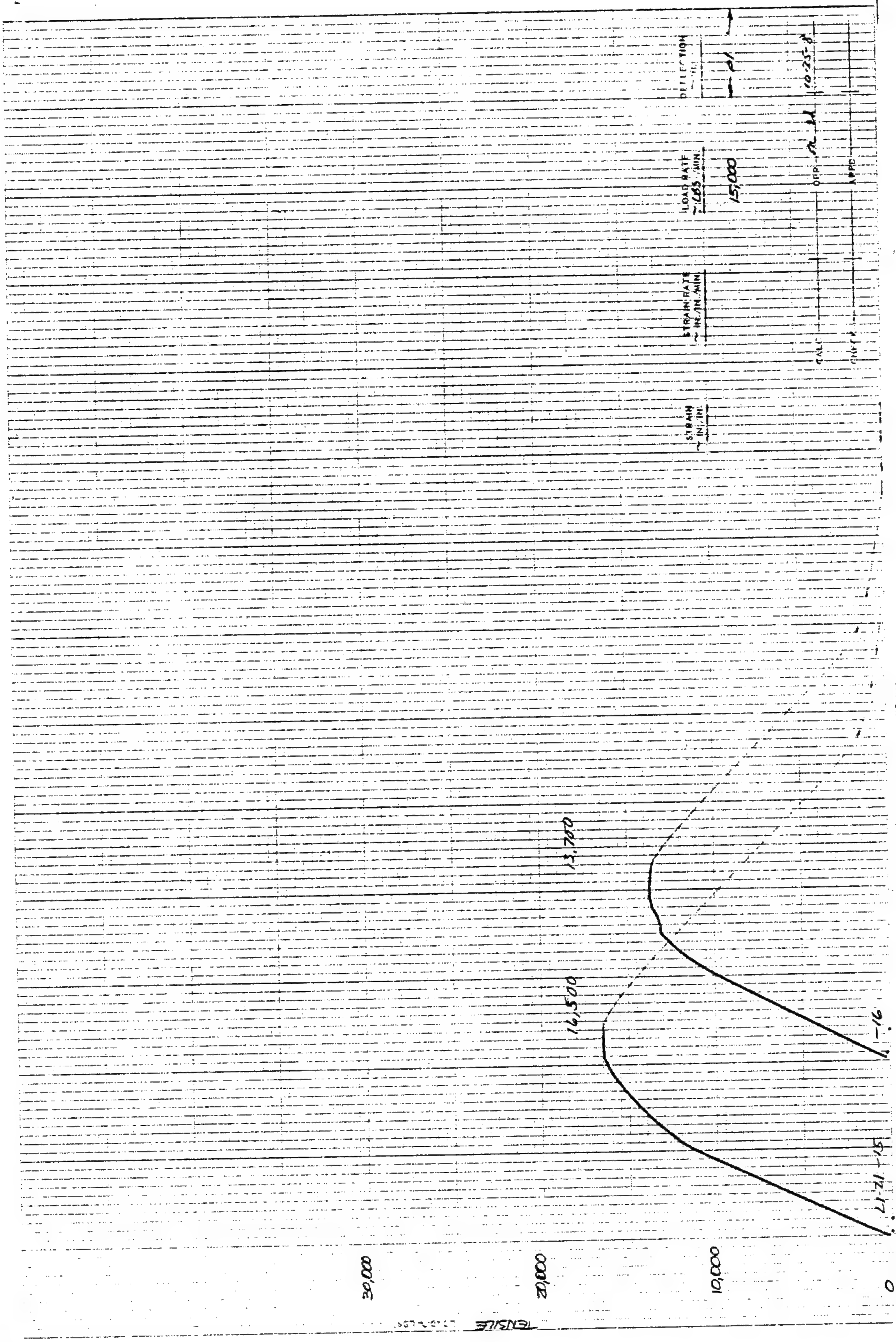
AFTER MOISTURE CONDITIONING







15,200
16,100
10,400
10,400
-14
-13
-16
L1-21-13
0
5000
10,000
15,000
20,000
0
4000
8000
12,000
16,000
15,000
.005
TENSILE



TENSILE
30,000
20,000
10,000
0
14,500
13,700
1-17-21-15
-16
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE
15,000
DEFLECTION
.01
CALC
CHECK
APPD

LAMINATE L1

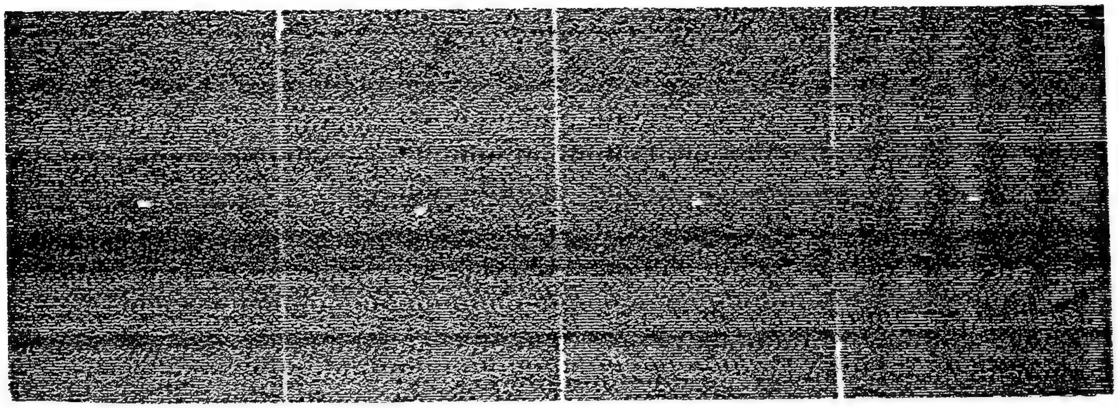
1/8 FP SLIT

TEST SPECIMENS

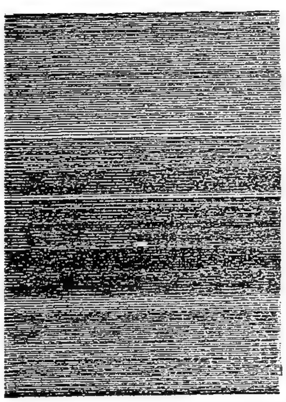
ROOM TEMPERATURE | 422° K (300° F)

L1-21-21 | L1-21-22 | L1-21-23 | L1-21-24

INITIAL



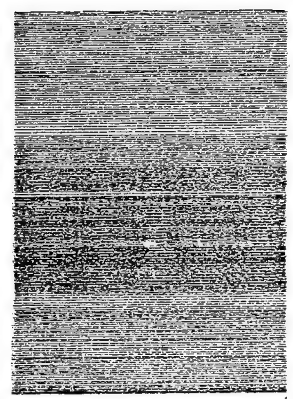
AFTER PRELOAD 15.9 KIP



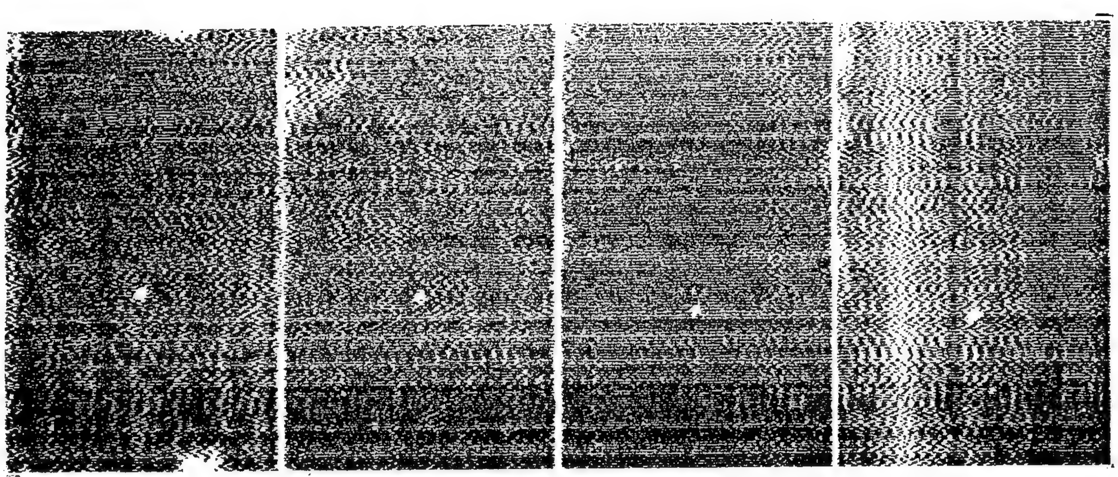
VISUAL DAMAGE

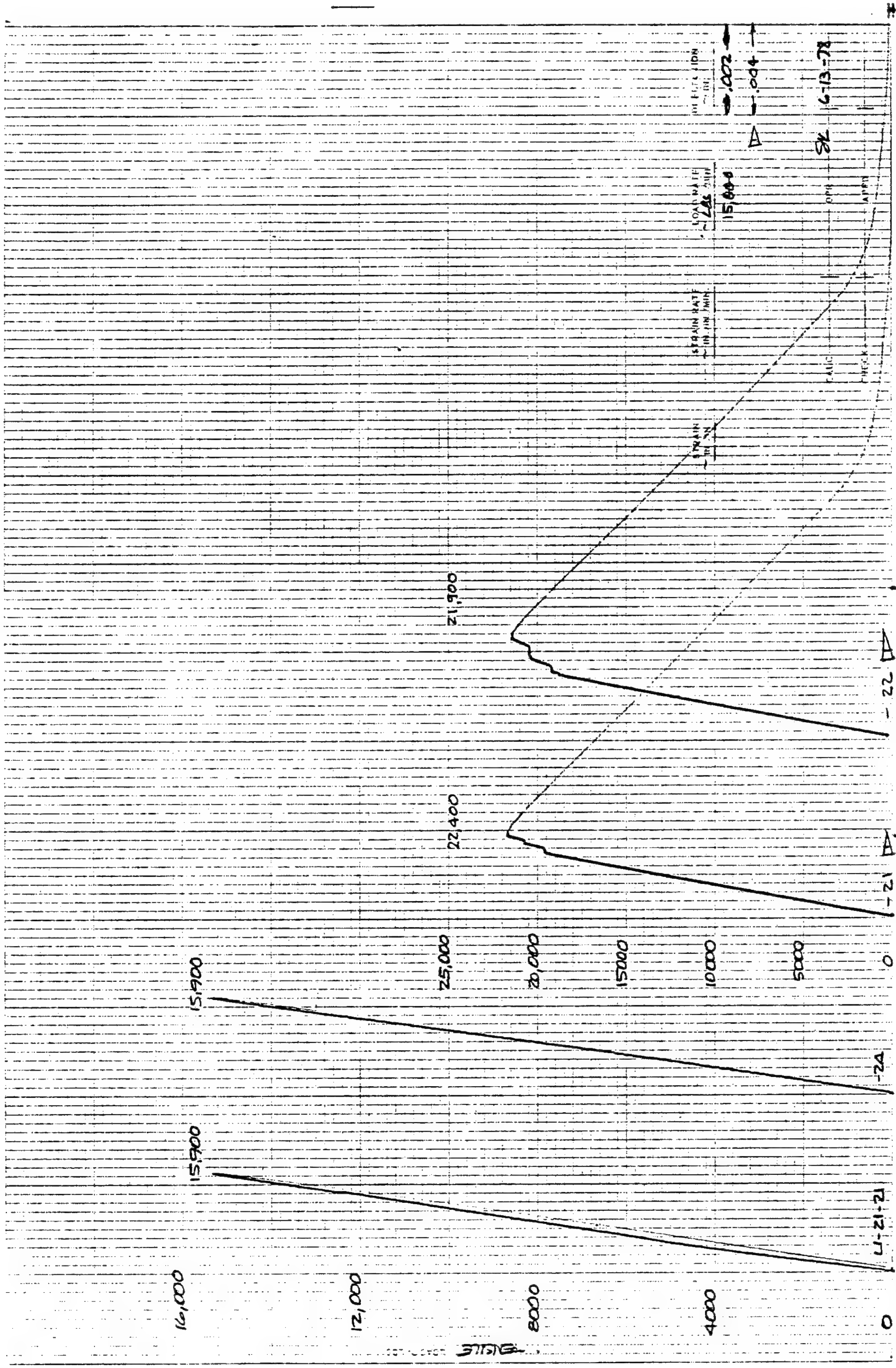
← NONE

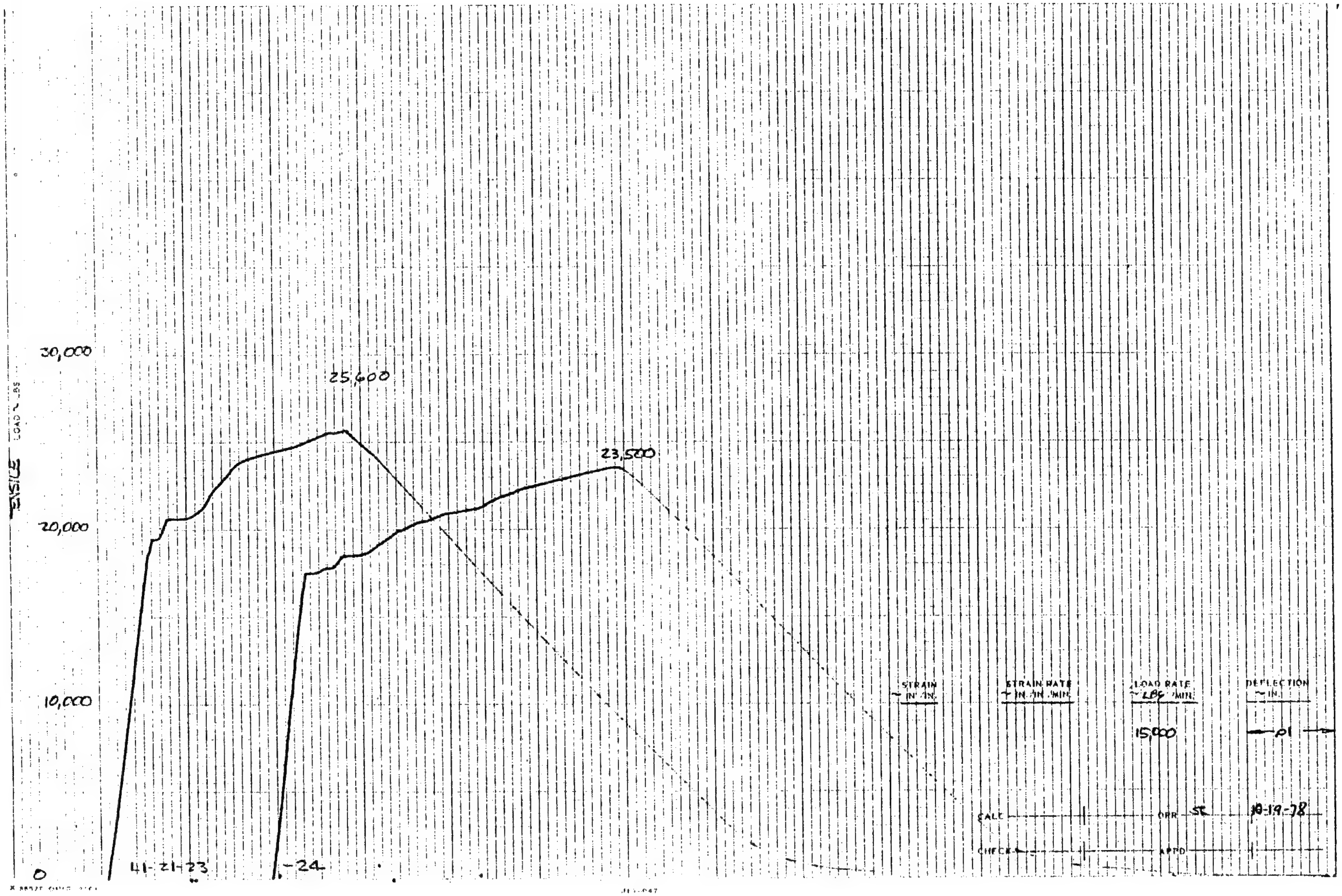
0.1 inch FINE CRACK →



AFTER MOISTURE CONDITIONING




16,000
12,000
8000
4000
0
17-21-21
15,900
-24
15,900
25,000
20,000
15000
10000
5000
0
-21
22,400
-22
21,900
.002
.004
15,000
6-13-78



TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
25,600
23,500
41-21-23
-24
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS/MIN
15,000
DEFLECTION ~ IN.
.01
CALC
OPR ST
10-19-78
CHECK
APPD

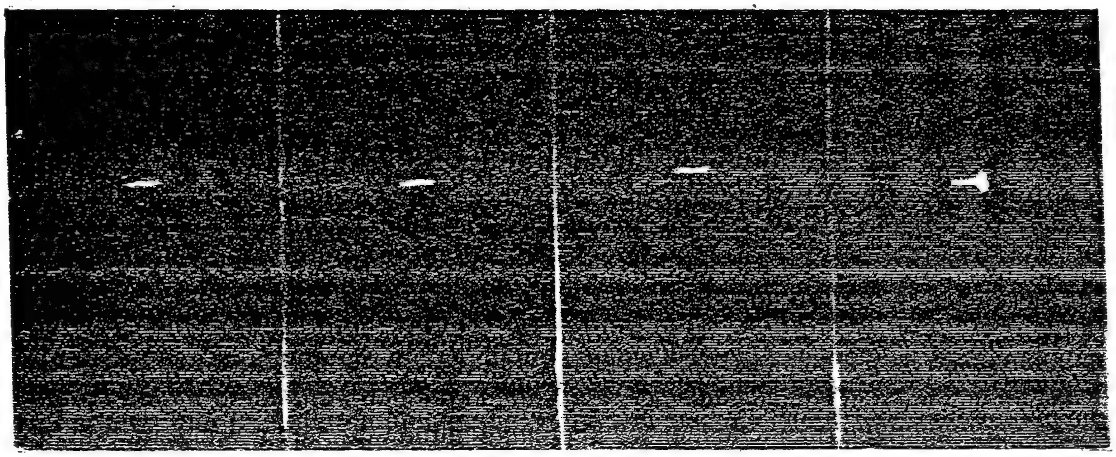
LAMINATE L1
3/8 FP SLIT

TEST SPECIMENS

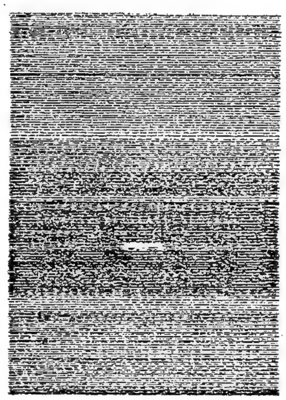
ROOM TEMPERATURE | 422° K (300° F)

L1-21-25 L1-21-26 L1-21-27 L1-21-28

INITIAL

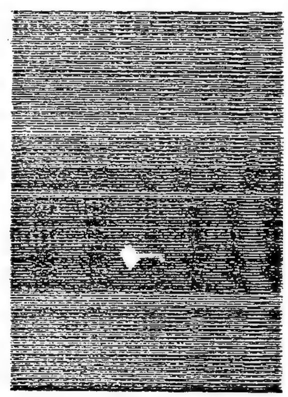


AFTER PRELOAD 12.7 KIP

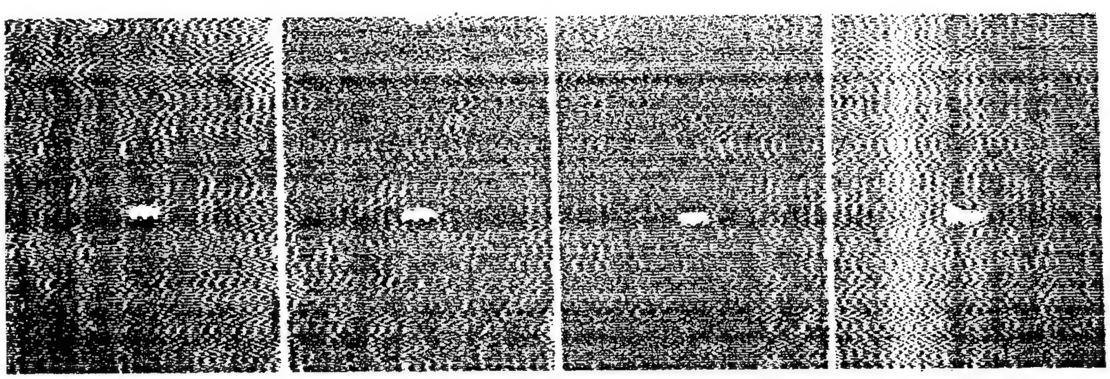


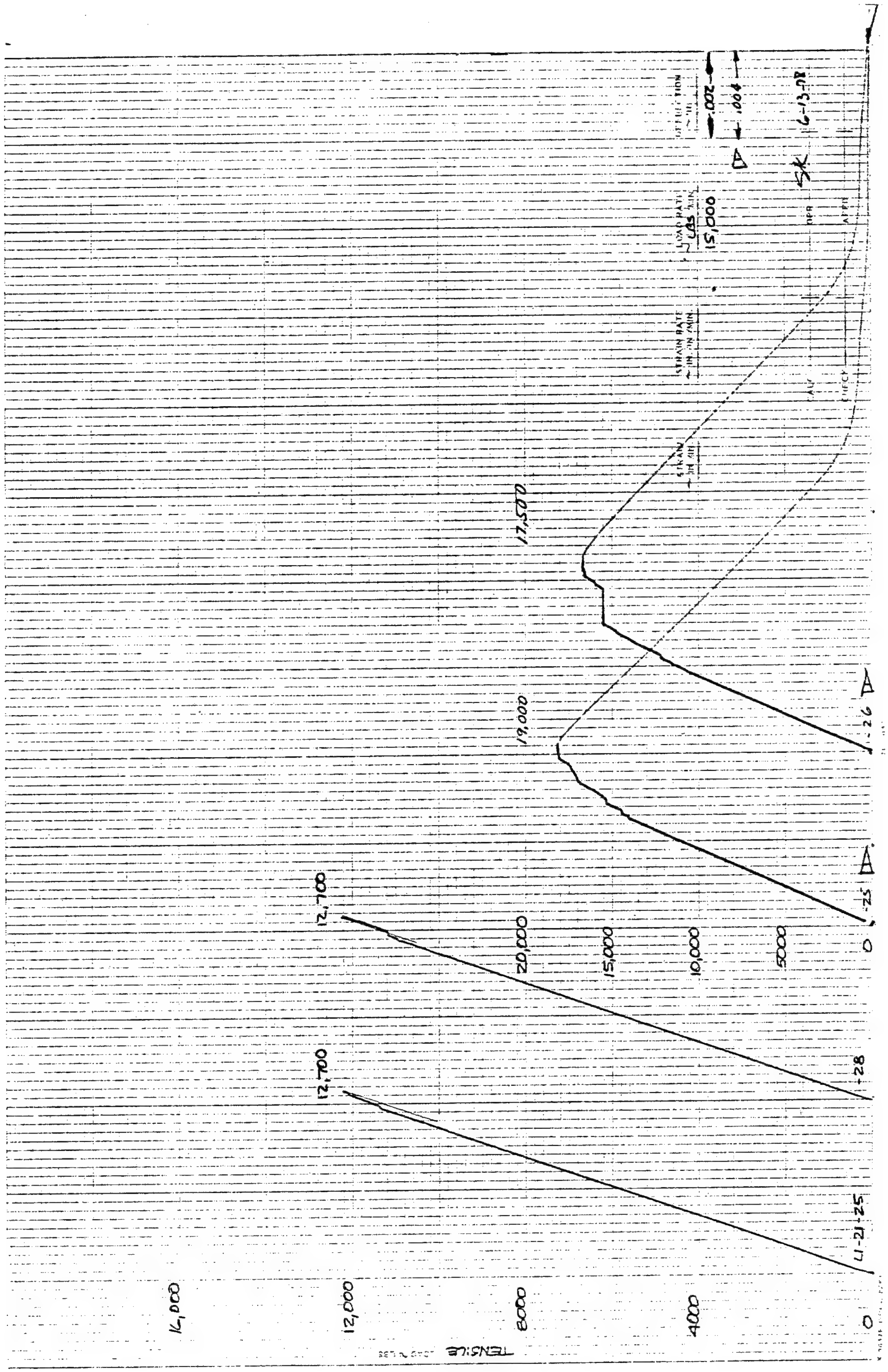
VISUAL DAMAGE

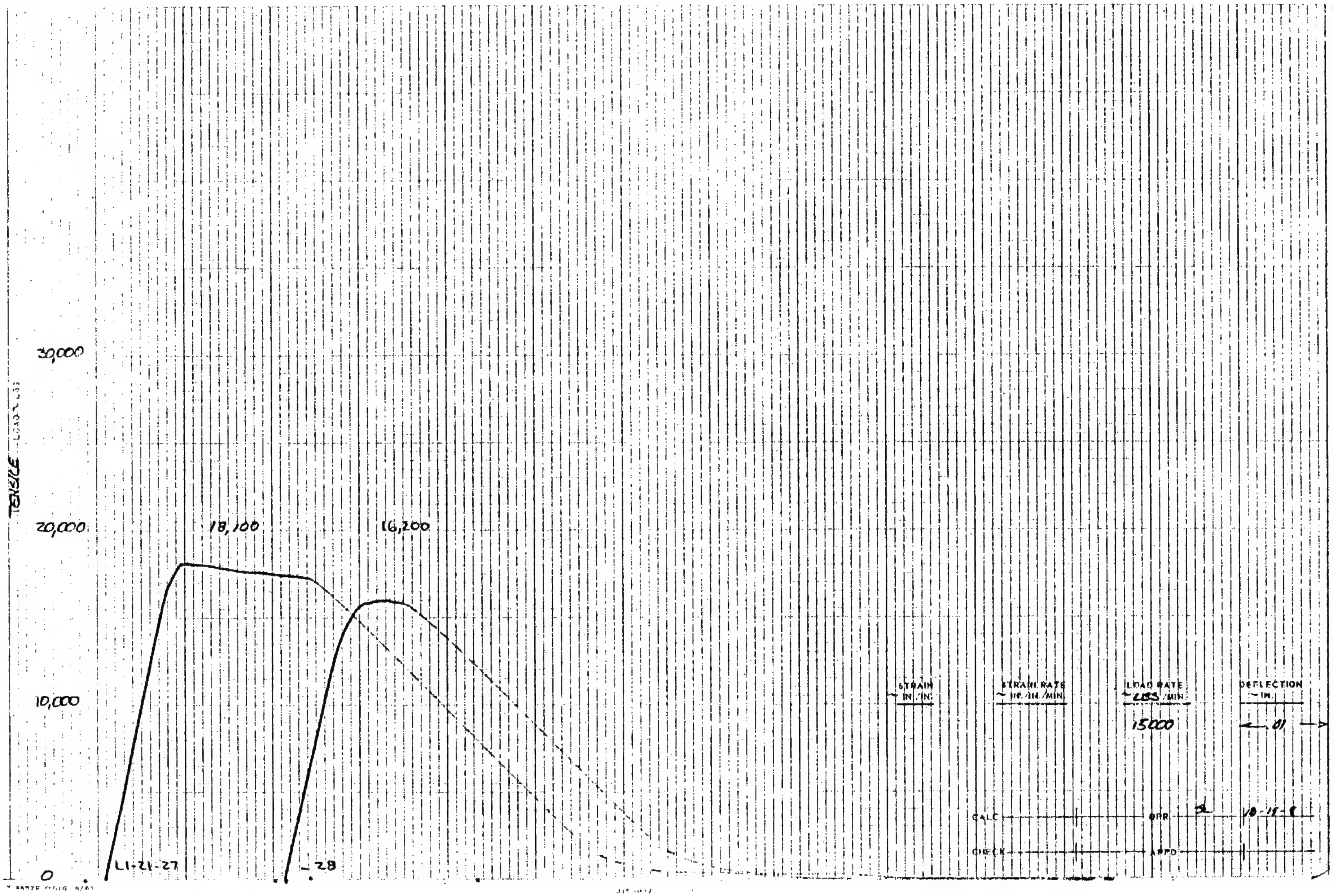
← NONE →



AFTER MOISTURE CONDITIONING




TENSILE
16,000
12,000
8000
4000
0
20,000
15,000
10,000
5000
0
L1-21-25
12,700
.28
12,700
.25
19,000
.26
17,500
15,000
.200
.1004
6-13-78


TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
18,100
16,200
L1-21-27
-28
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE ~ LBS/MIN.
15000
DEFLECTION ~ IN.
.01
CALC
DRR
10-15-8
CHECK
APPD

LAMINATE L1

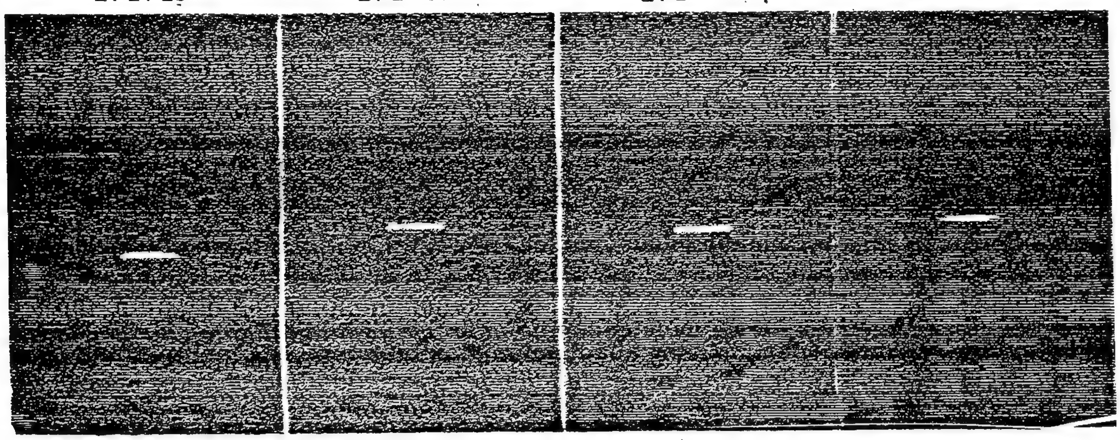
5/8 FP SLIT

TEST SPECIMENS

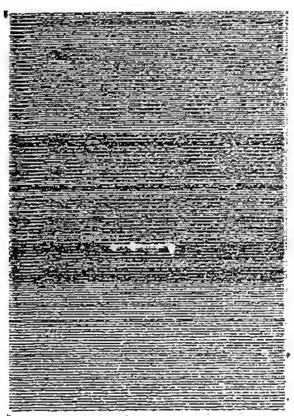
ROOM TEMPERATURE | 422° K (300° F)

L1-21-29 | L1-21-30 | L1-21-31 | L1-21-32

INITIAL

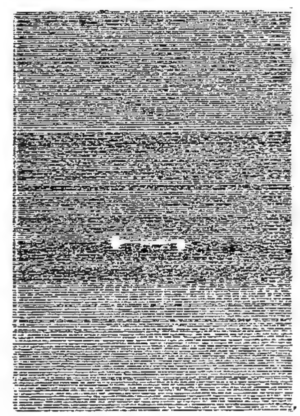


AFTER PRELOAD 10.6 KIP

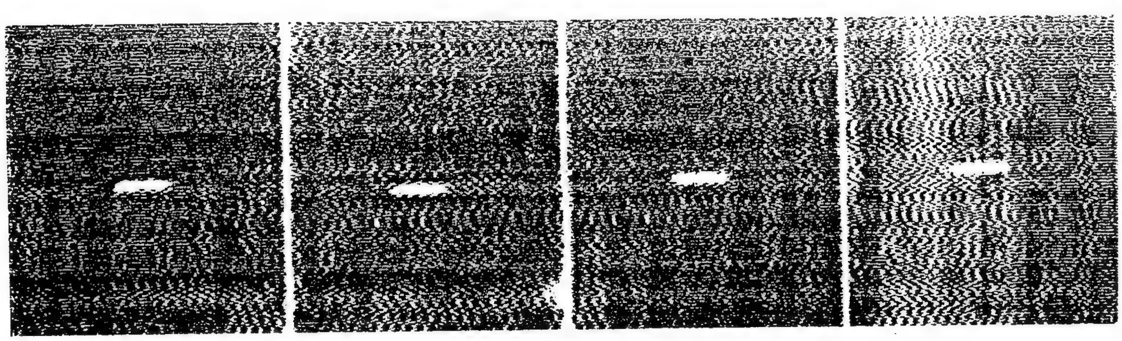


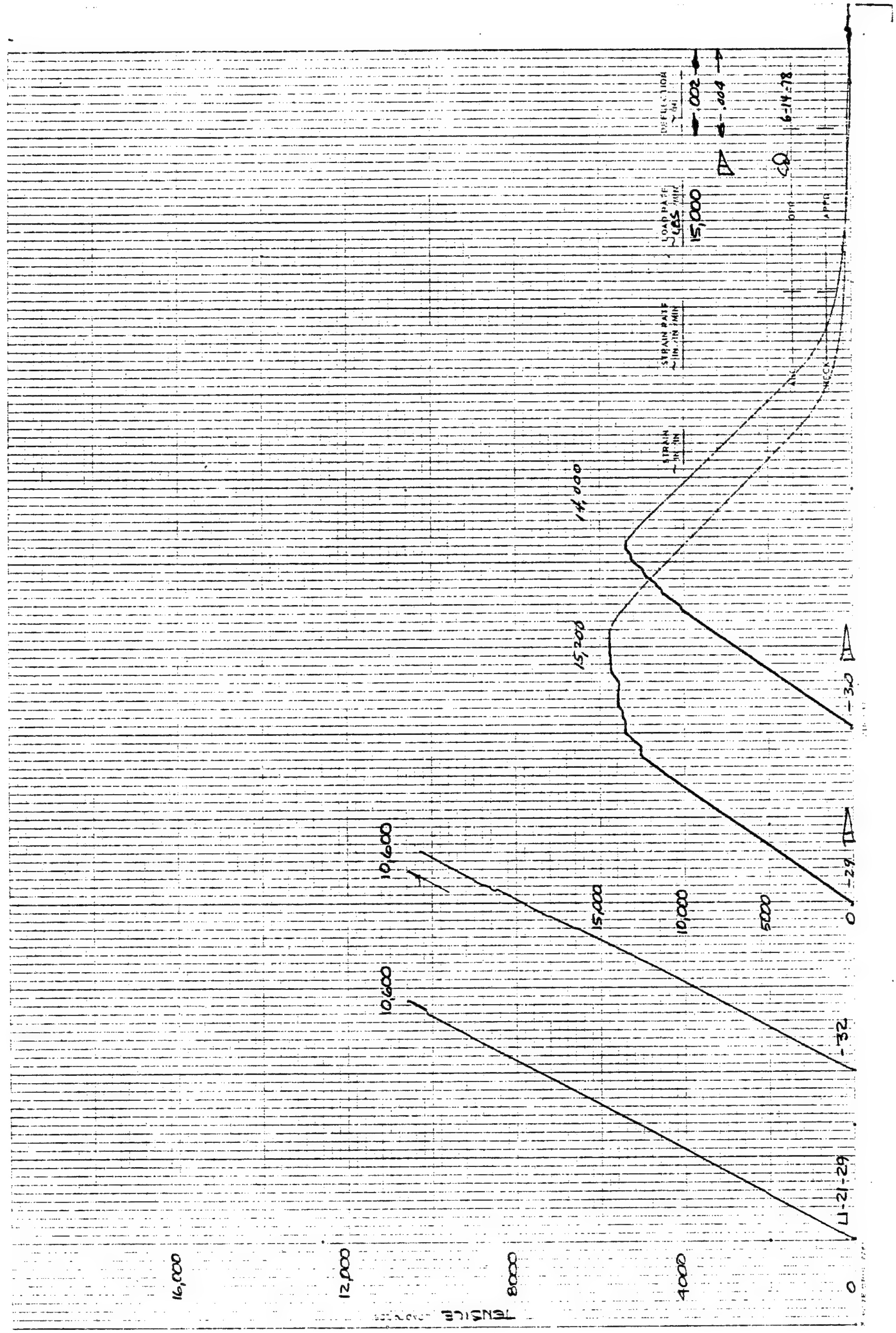
VISUAL DAMAGE

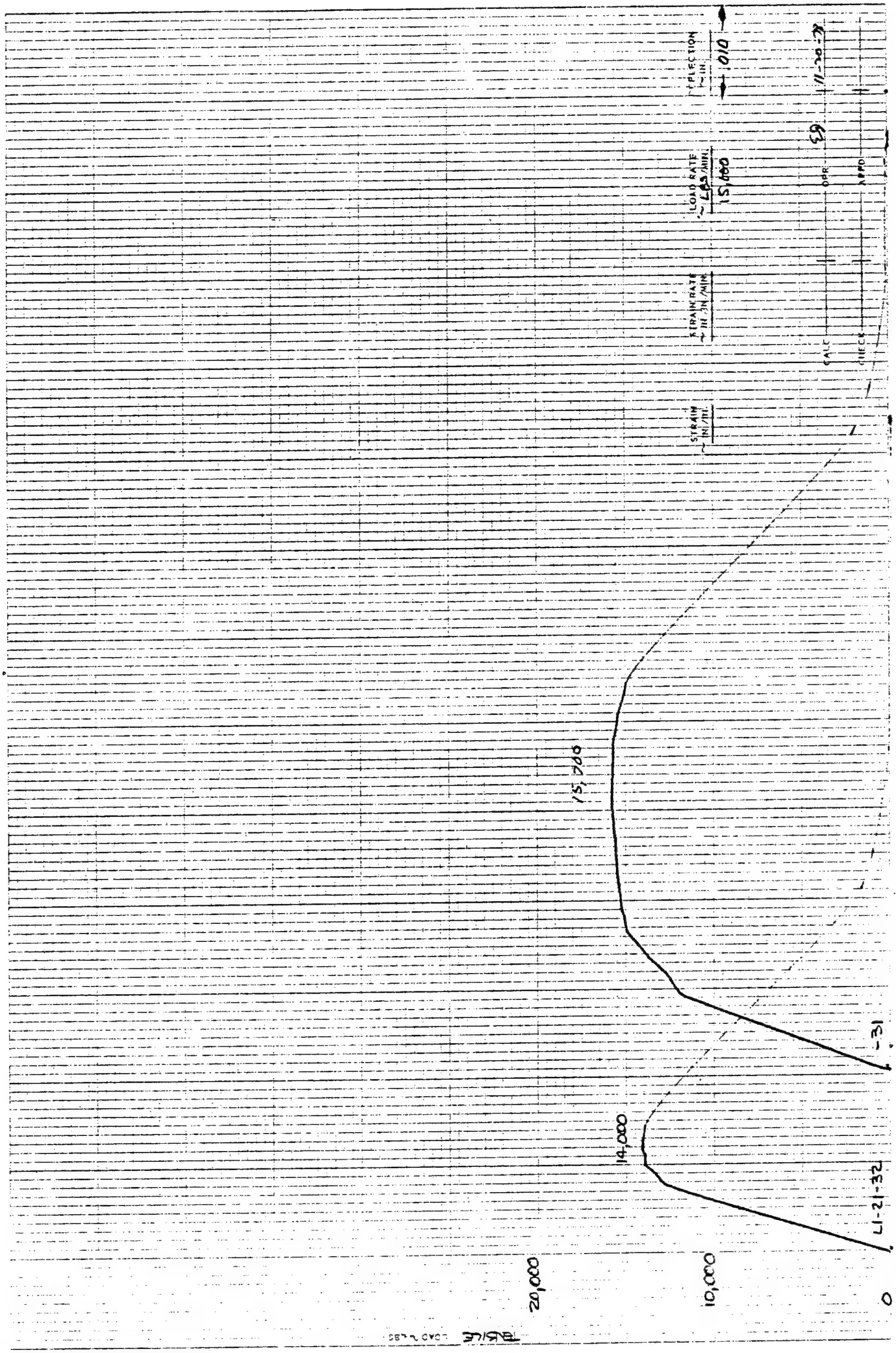
← FINE SPLITS →



AFTER MOISTURE CONDITIONING




TENSILE
16,000
12,000
8000
4000
0
L1-21-29
10,600
-32
10,600
15,000
10,000
5000
0
-29
-30
15,200
14,000
STRAIN ~IN/IN
STRAIN RATE ~IN/IN/MIN
LOAD RATE ~LBS/MIN
15,000
DEFLECTION ~IN
.002
.004
6-14-78


TENSILE LOAD ~ LBS
20,000
10,000
0
L1-21-32
14,000
-31
15,700
STRAIN ~ IN/IN.
STRAIN RATE ~ IN/IN/MIN.
LOAD RATE ~ LBS/MIN.
15,000
DEFLECTION ~ IN.
.010
CALC
CHECK
OPR
APPD
11-20-78

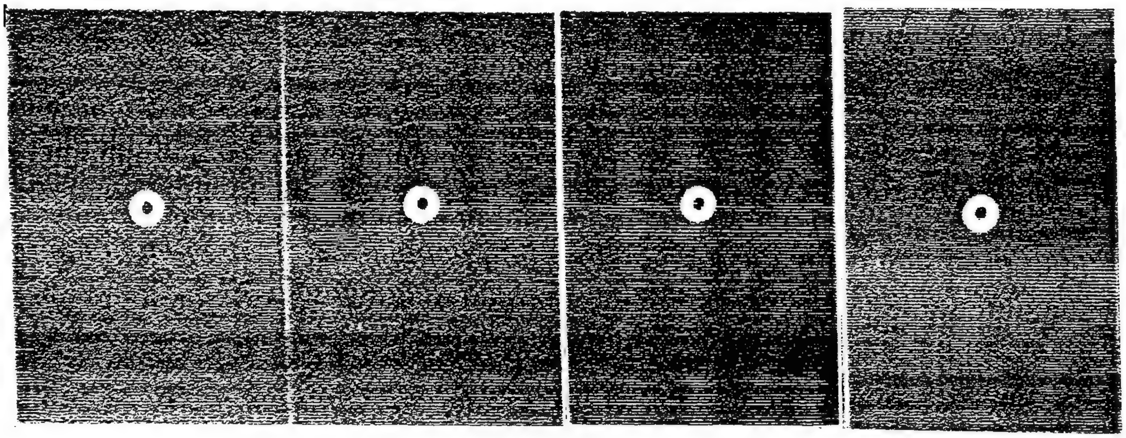
LAMINATE L1
1/8 CSK HOLE

TEST SPECIMENS

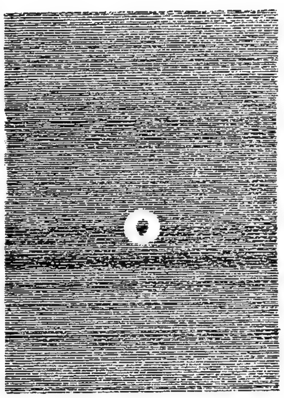
ROOM TEMPERATURE | 422° K (300° F)

L1-21-18 | L1-21-19 | L1-21-57 | L1-21-58

INITIAL



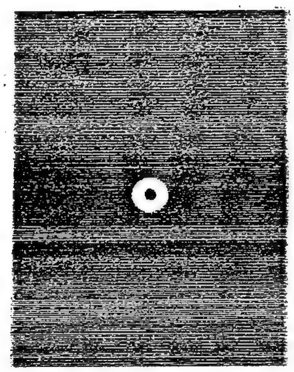
AFTER PRELOAD 13.7 KIP



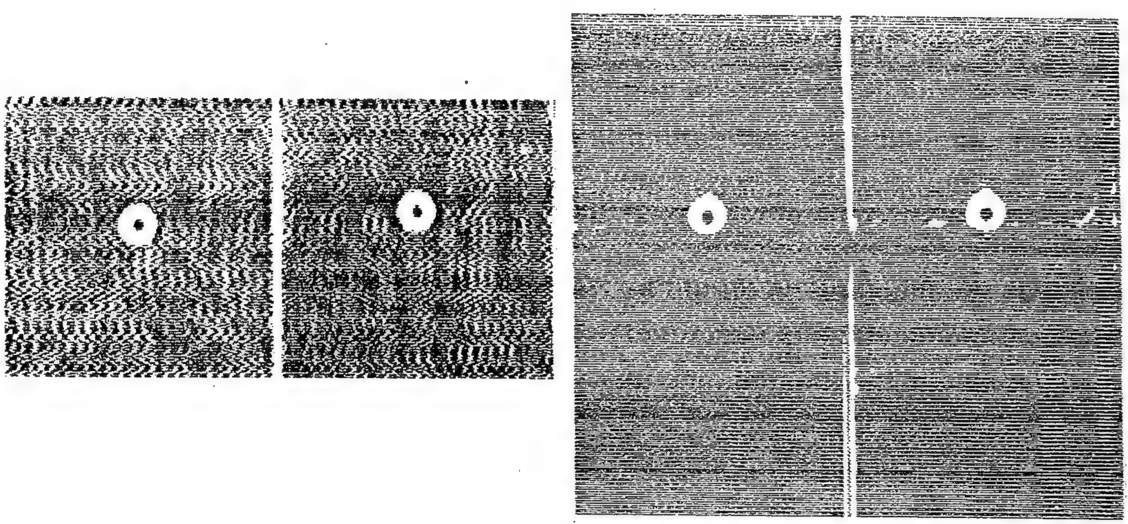
VISUAL DAMAGE

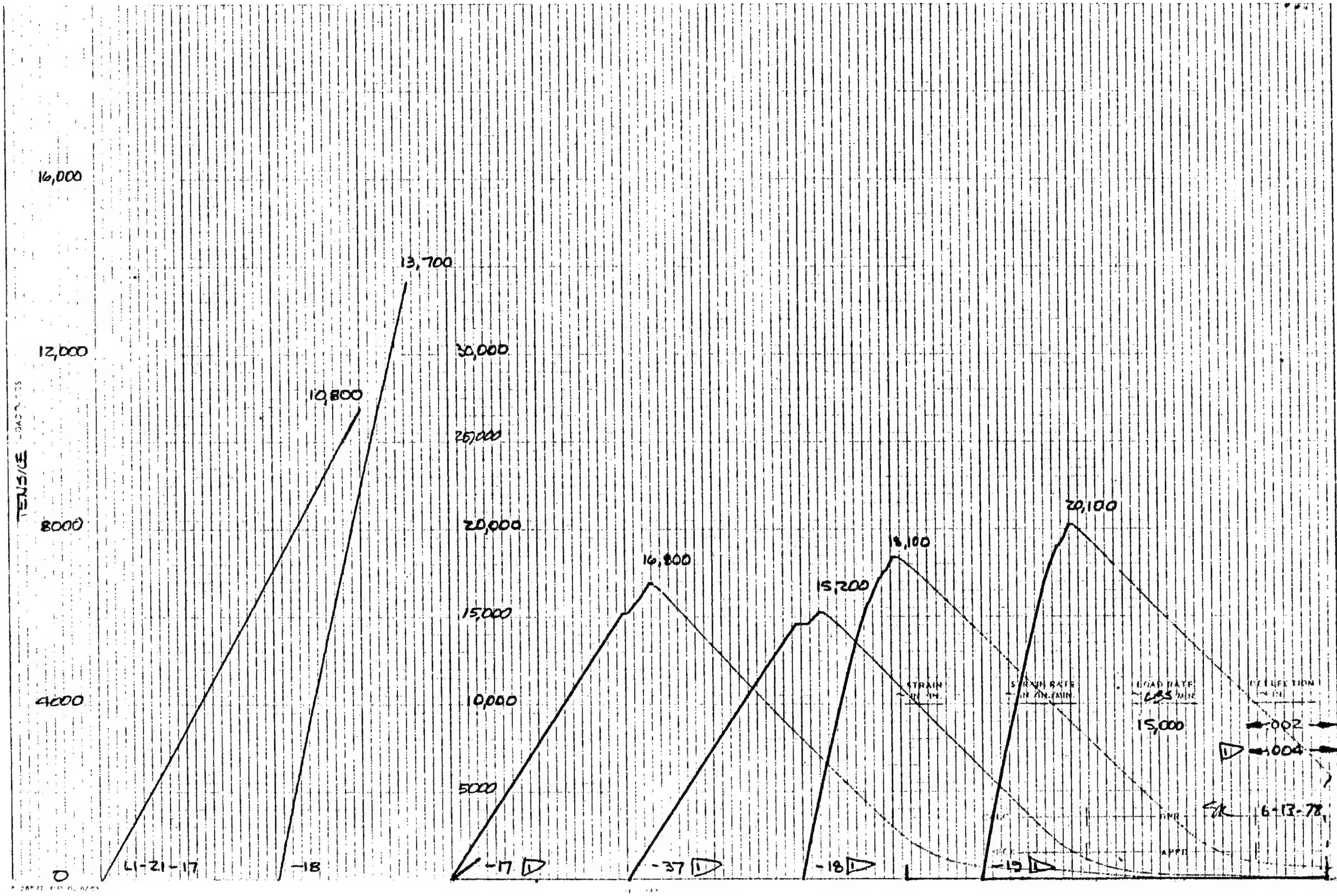
← NONE

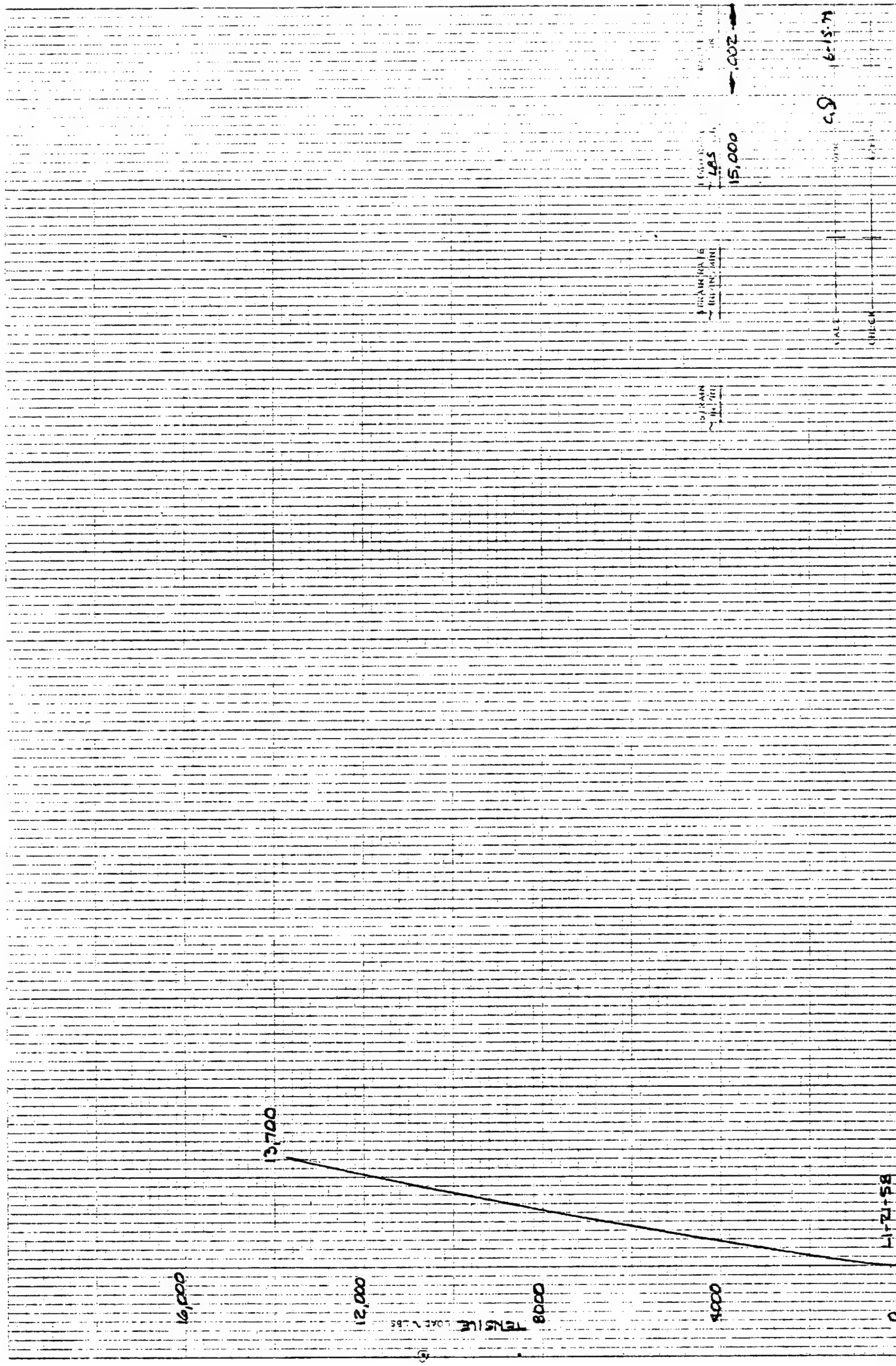
FINE SPLITS ON BACK →

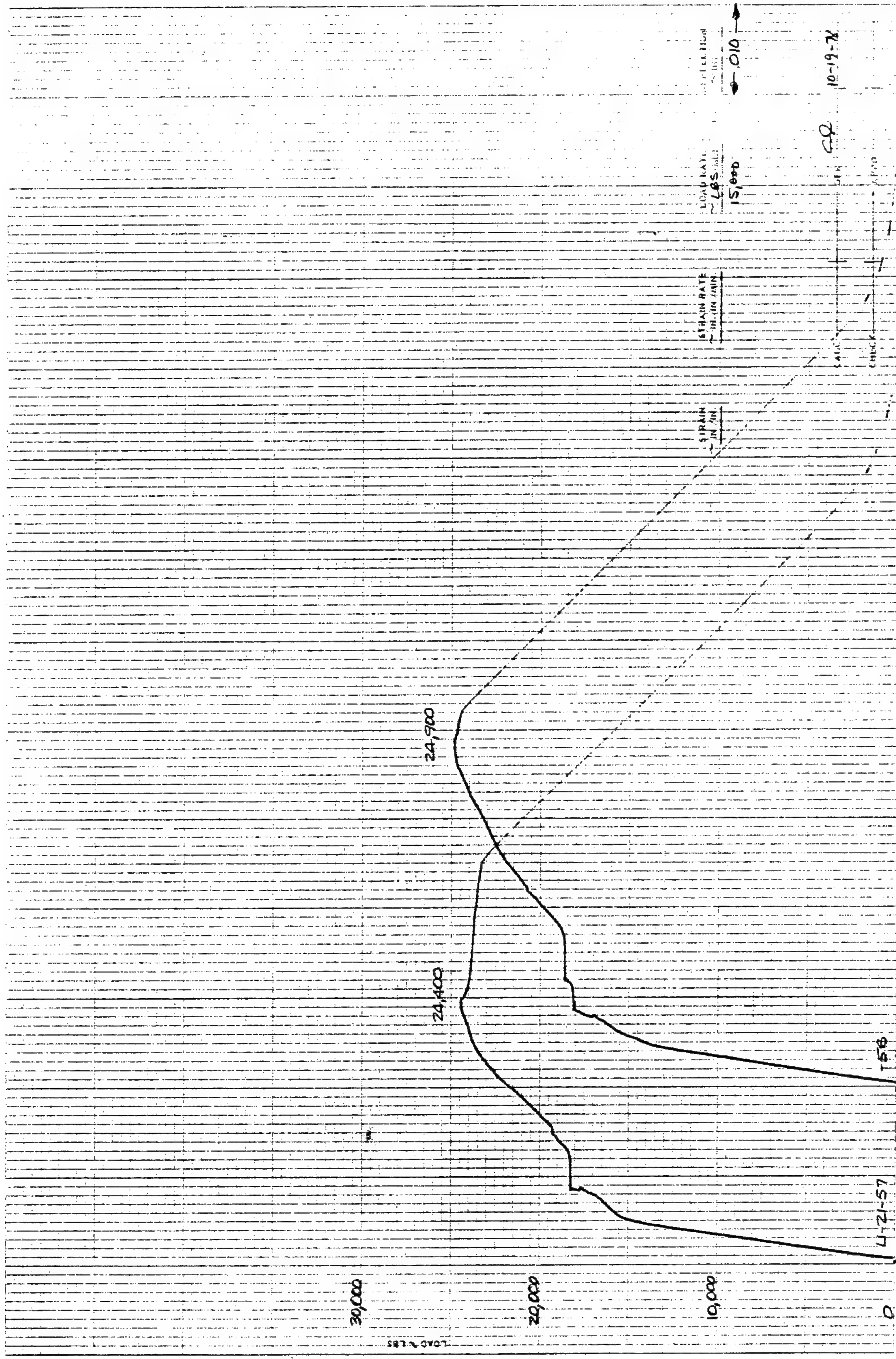


AFTER MOISTURE CONDITIONING

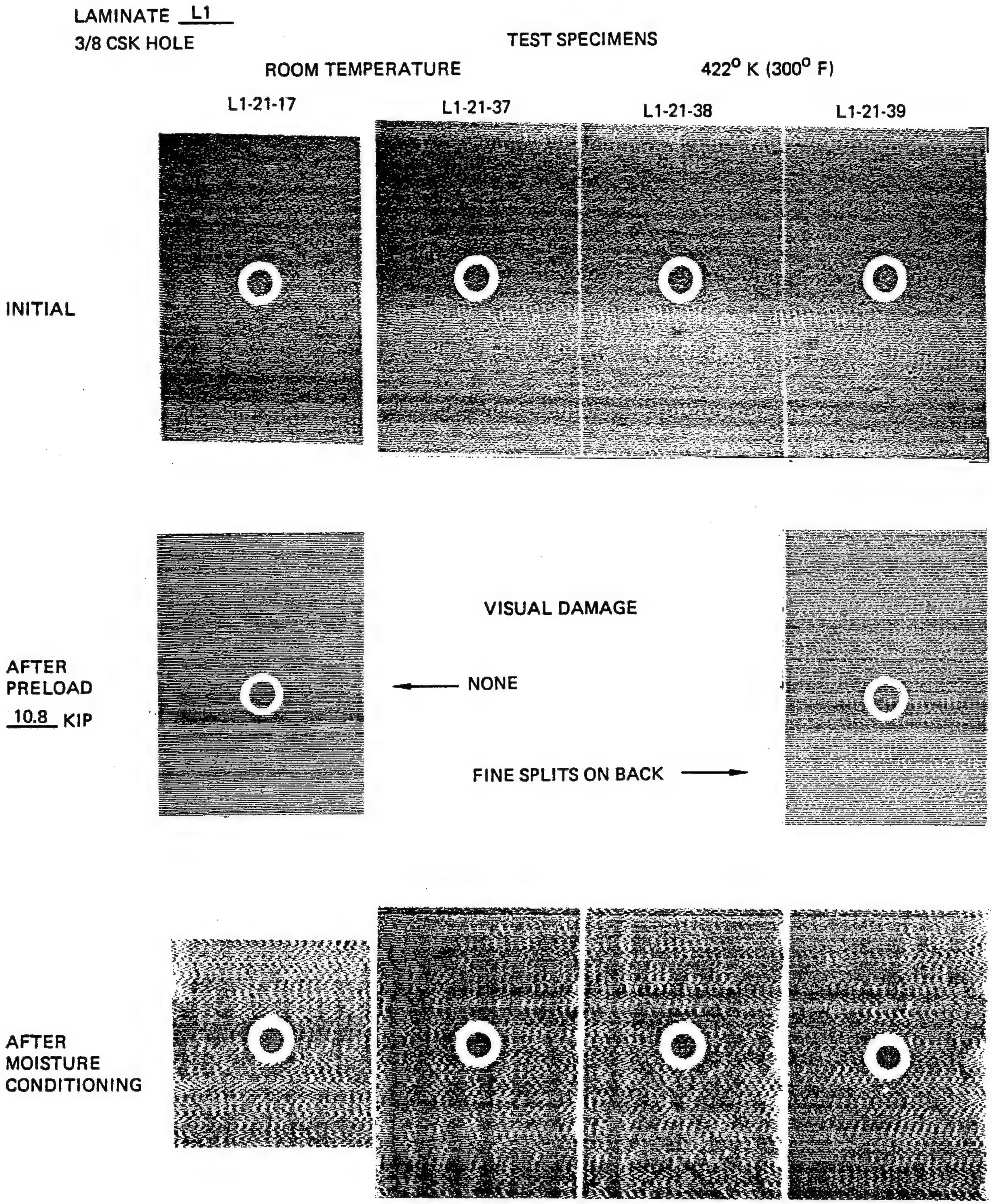



TENSILE
16,000
12,000
8000
4000
0
L1-21-17
-18
13,700
10,800
30,000
25,000
20,000
15,000
10,000
5000
-17
-37
-18
-19
16,800
15,200
18,100
20,100
STRAIN
STRAIN RATE
LOAD RATE
DEFLECTION
15,000
.002
.004
6-13-78

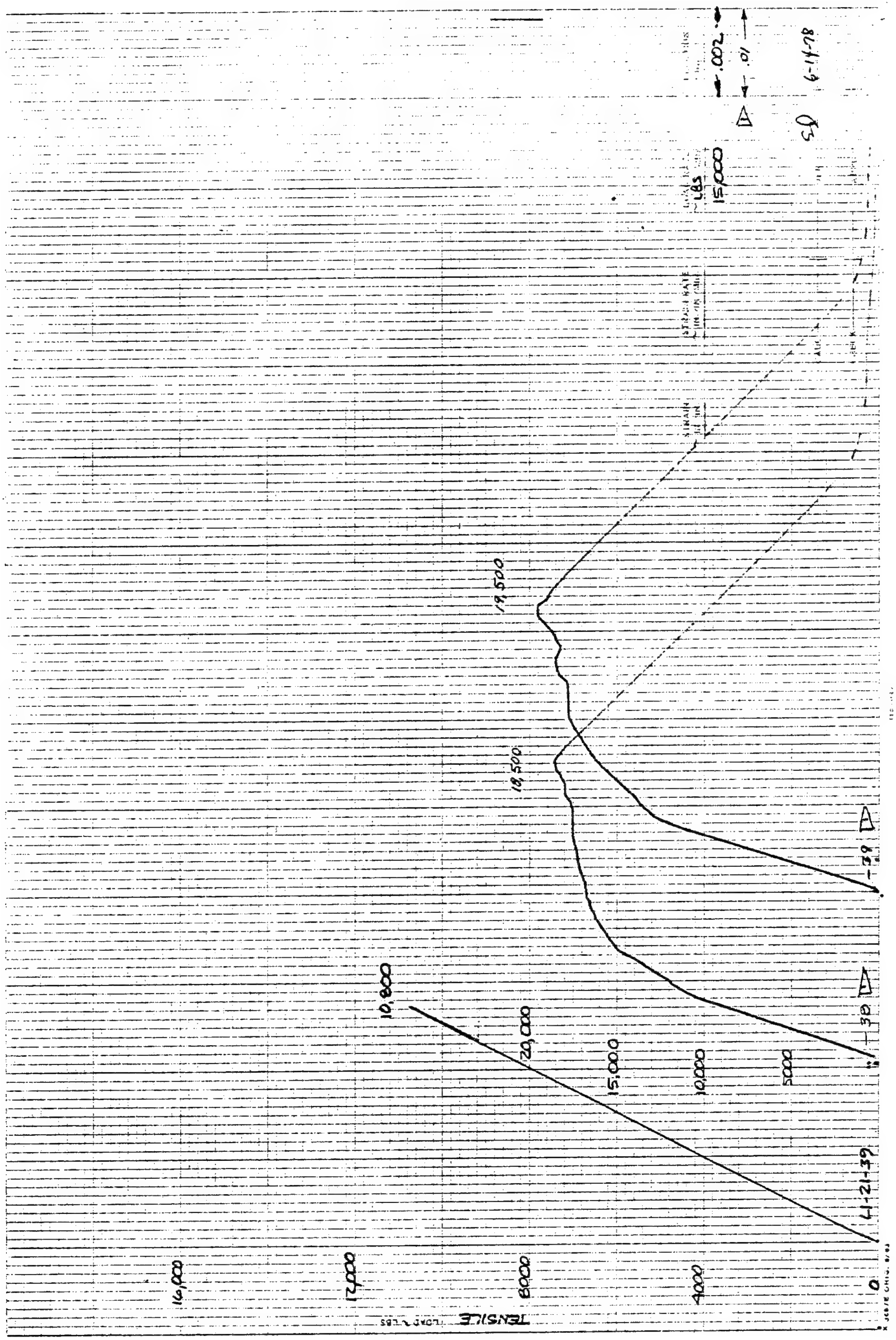

13,700
16,000
12,000
8000
4000
0
TENSILE
15,000
.002



24,900
24,400
T56
4-21-57
30,000
20,000
10,000
0
LOAD ~ LBS
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS/MIN
15,000
DEFLECTION
.010
10-19-78
CALC
CHECK



LAMINATE L1
3/8 CSK HOLE
TEST SPECIMENS
ROOM TEMPERATURE
422° K (300° F)
L1-21-17
L1-21-37
L1-21-38
L1-21-39
INITIAL
VISUAL DAMAGE
AFTER
PRELOAD
10.8 KIP
NONE
FINE SPLITS ON BACK
AFTER
MOISTURE
CONDITIONING


TENSILE LOAD LBS
16,000
12,000
8000
4000
0
L1-21-39
10,800
20,000
15,000
10,000
5000
-38
-39
18,500
19,500
LBS
15,000
.002
.01
6-14-78

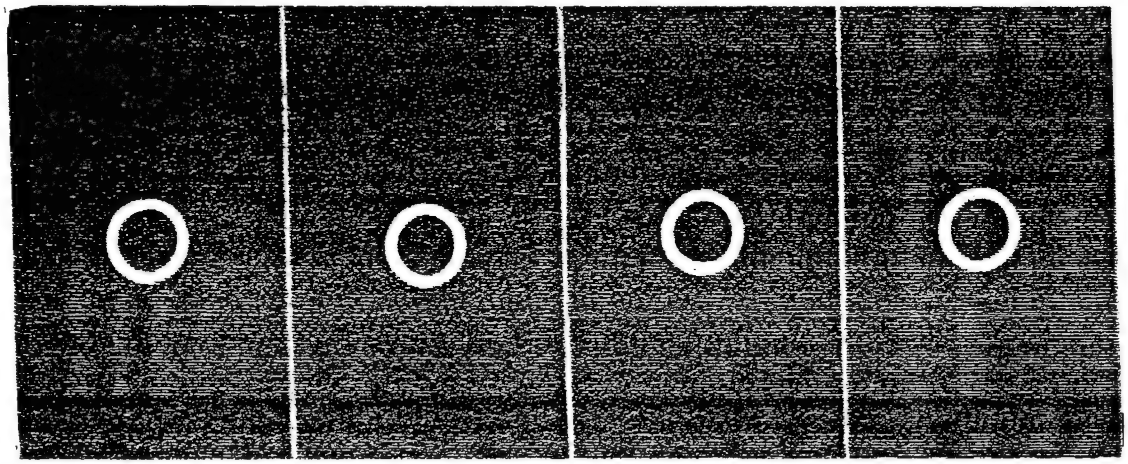
LAMINATE L1
5/8 CSK HOLE

TEST SPECIMENS

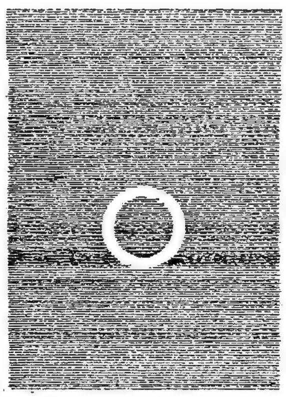
ROOM TEMPERATURE | 422° K (300° F)

L1-21-33 | L1-21-34 | L1-21-35 | L1-21-36

INITIAL

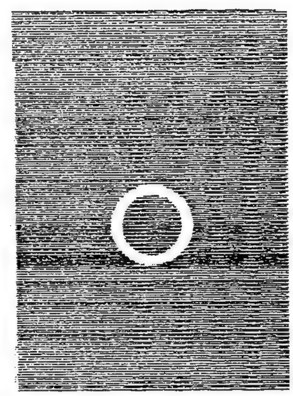


AFTER PRELOAD
8.9 KIP

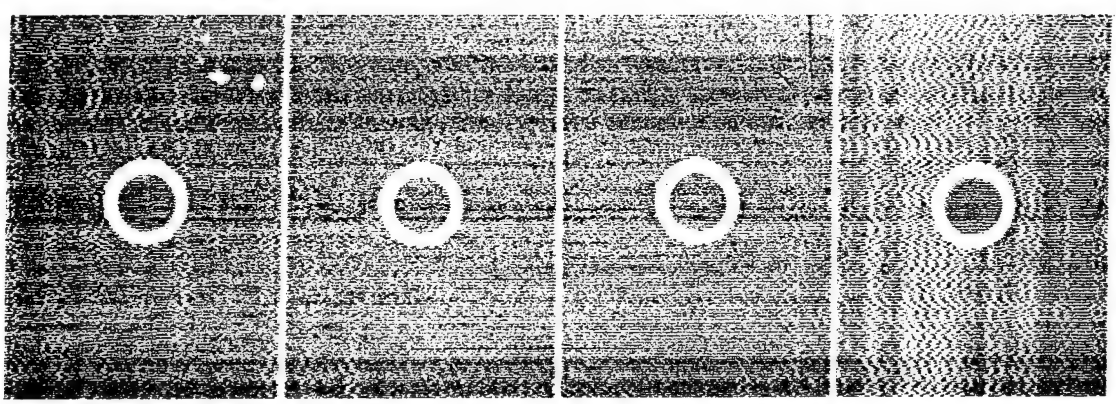


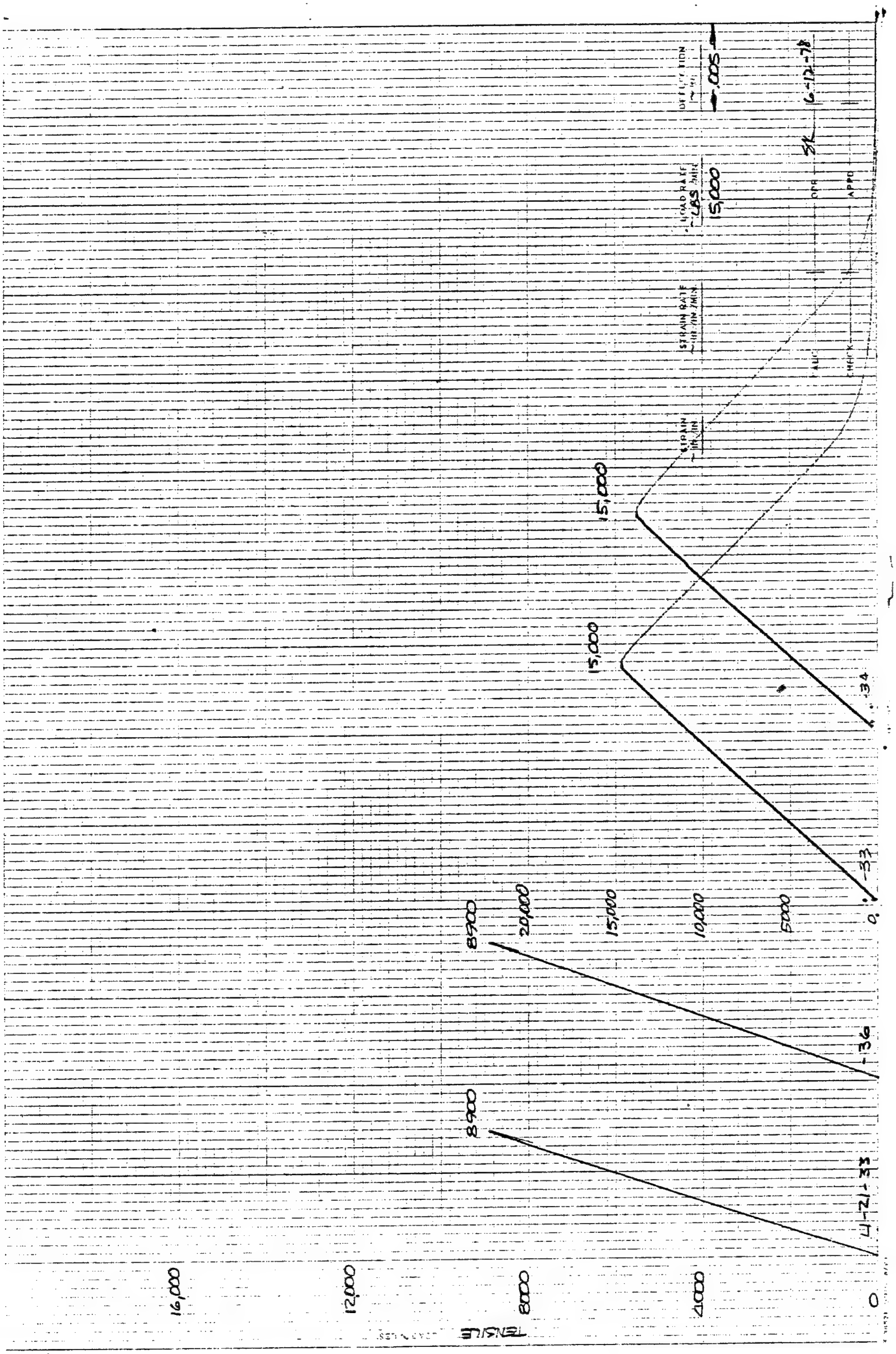
VISUAL DAMAGE

← NONE →

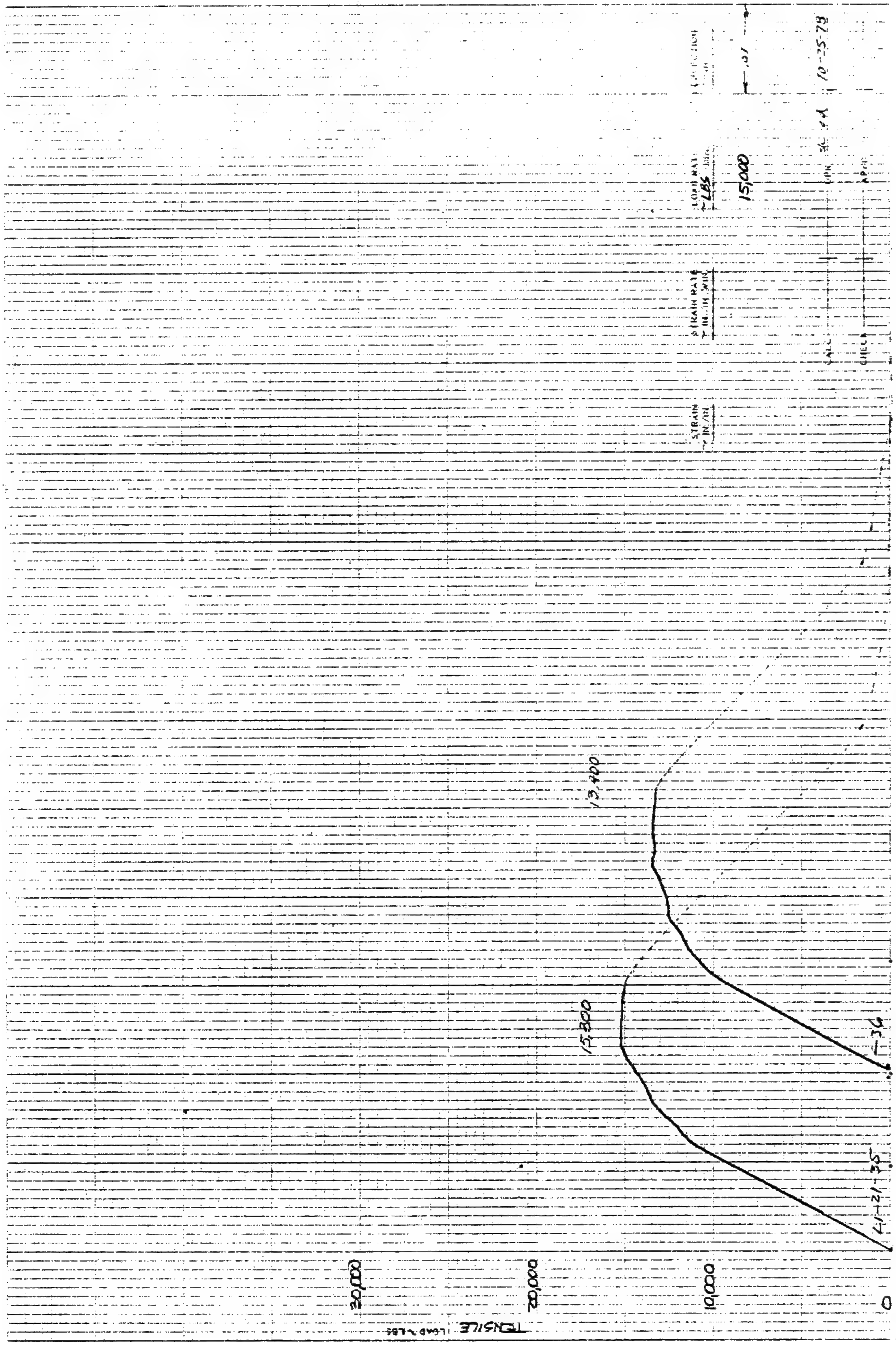


AFTER MOISTURE CONDITIONING

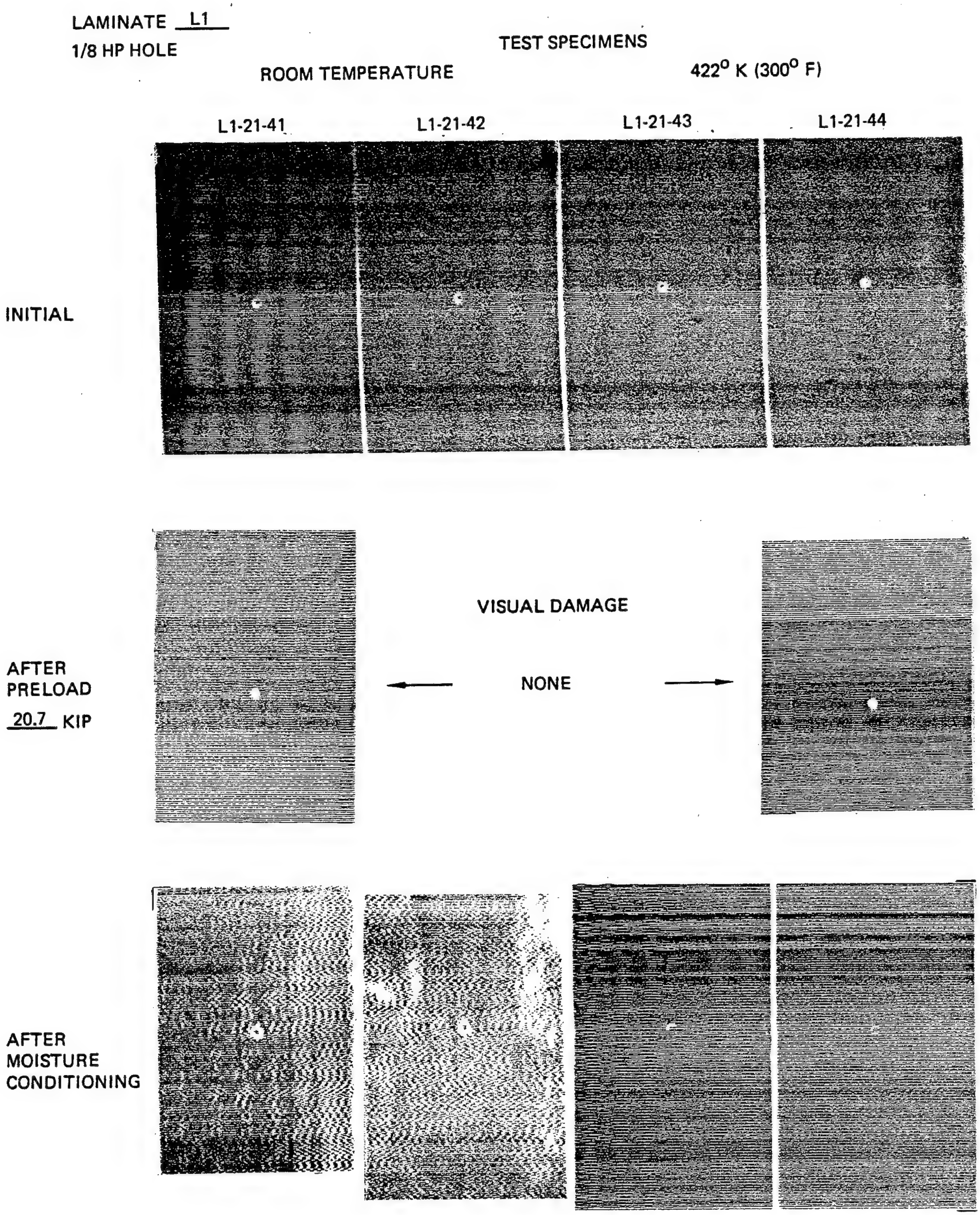


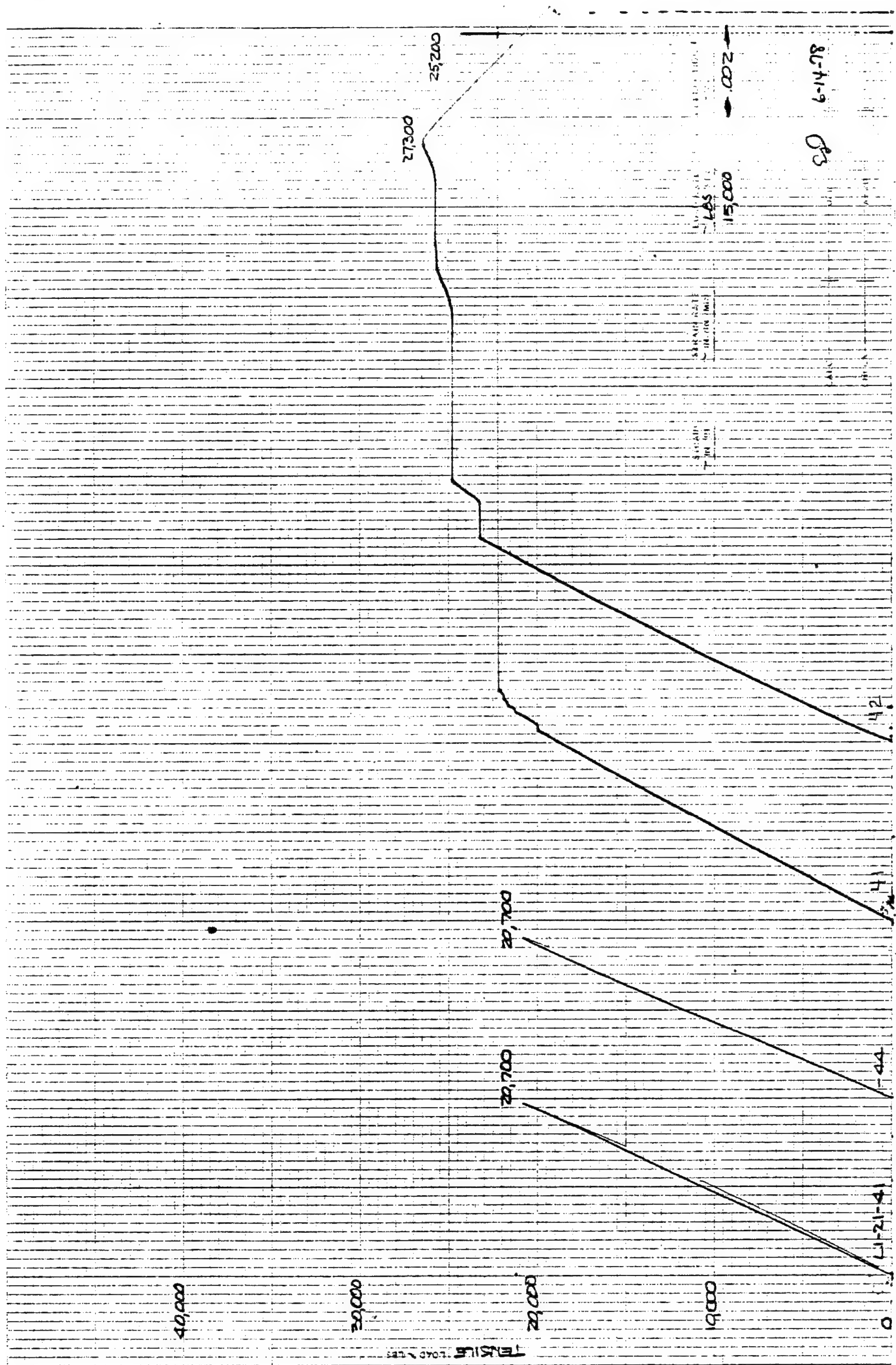


TENSILE
16,000
12,000
8000
4000
0
4-21-33
8900
-36
8900
20,000
15,000
10,000
5000
0
-33
15,000
-34
15,000
STRAIN
STRAIN RATE
LOAD RATE LBS/MIN
15,000
DEFLECTION
.005
OPR
SK
6-12-78
CALC
CHECK
APPD

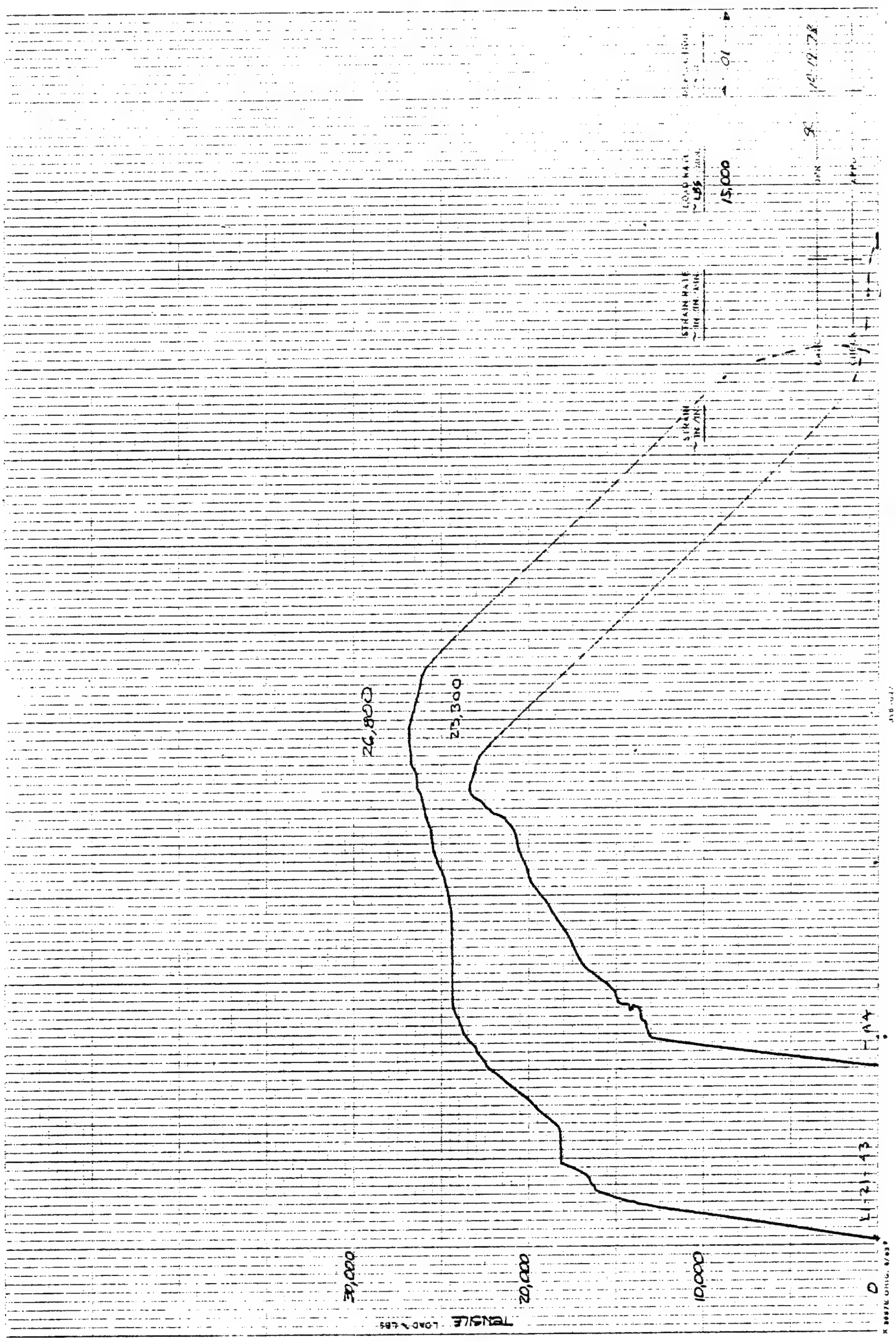


TENSILE LOAD ~LBS
0
10,000
20,000
30,000
15,300
13,400
LOAD RANGE ~LBS
15,000
STRAIN RATE
STRAIN ~IN/IN
10-25-78


LAMINATE L1
1/8 HP HOLE
TEST SPECIMENS
ROOM TEMPERATURE
422° K (300° F)
L1-21-41
L1-21-42
L1-21-43
L1-21-44
INITIAL
AFTER PRELOAD 20.7 KIP
VISUAL DAMAGE
NONE
AFTER MOISTURE CONDITIONING



25,200
27,300
.002
15,000
6-14-78
42
41
20,700
44
20,700
L1-21-41
40,000
30,000
20,000
10000
0
TENSILE LOAD LBS



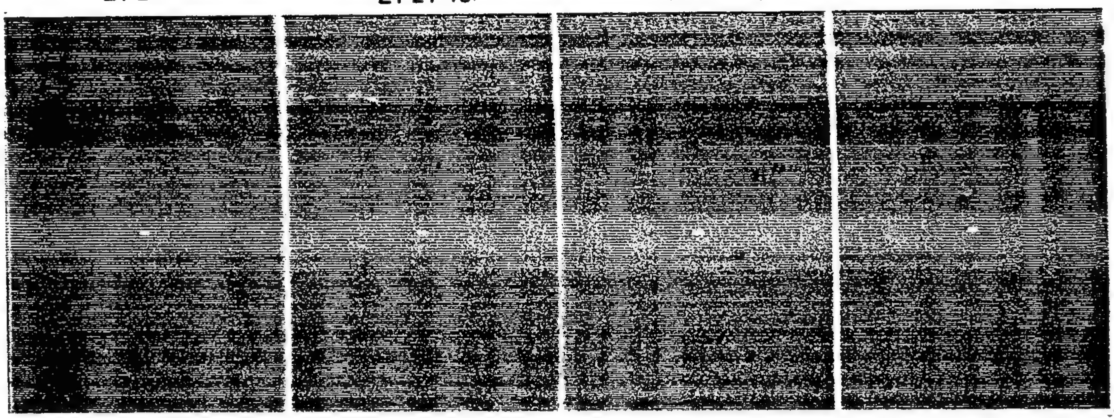
TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
26,800
23,300
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS/MIN
15,000

LAMINATE L1
1/8 HP SLIT

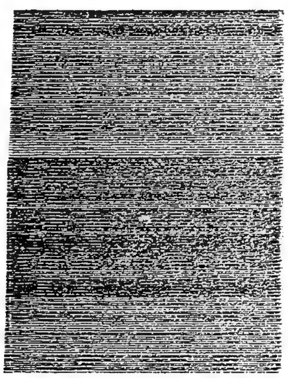
TEST SPECIMENS

	ROOM TEMPERATURE		422° K (300° F)	
	L1-21-45	L1-21-46	L1-21-47	L1-21-48

INITIAL

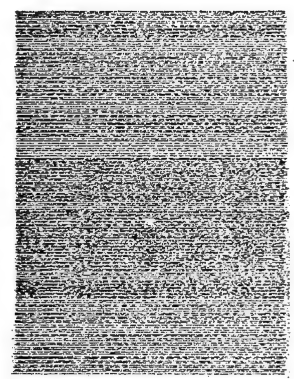


AFTER PRELOAD 19.1 KIP

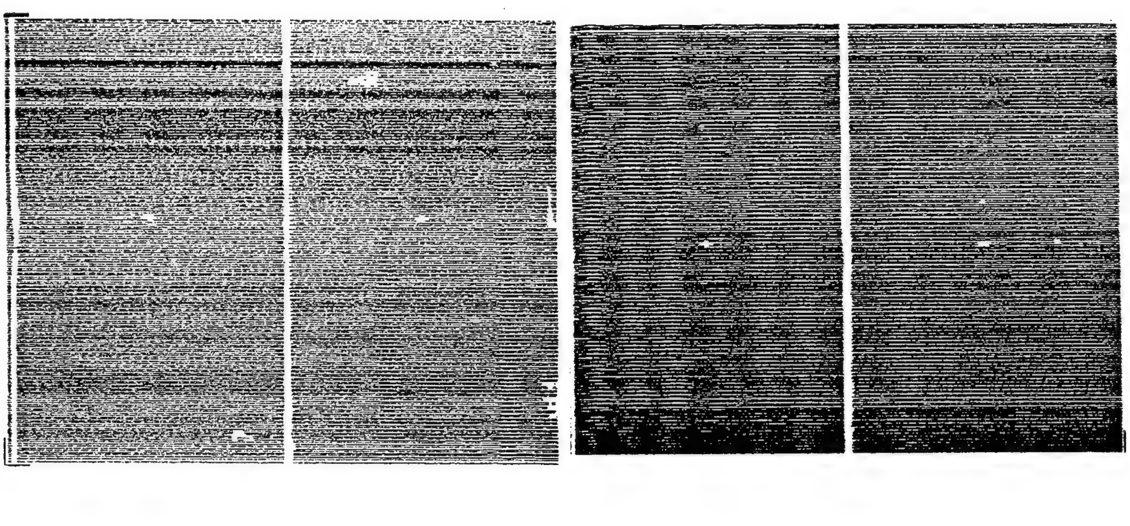


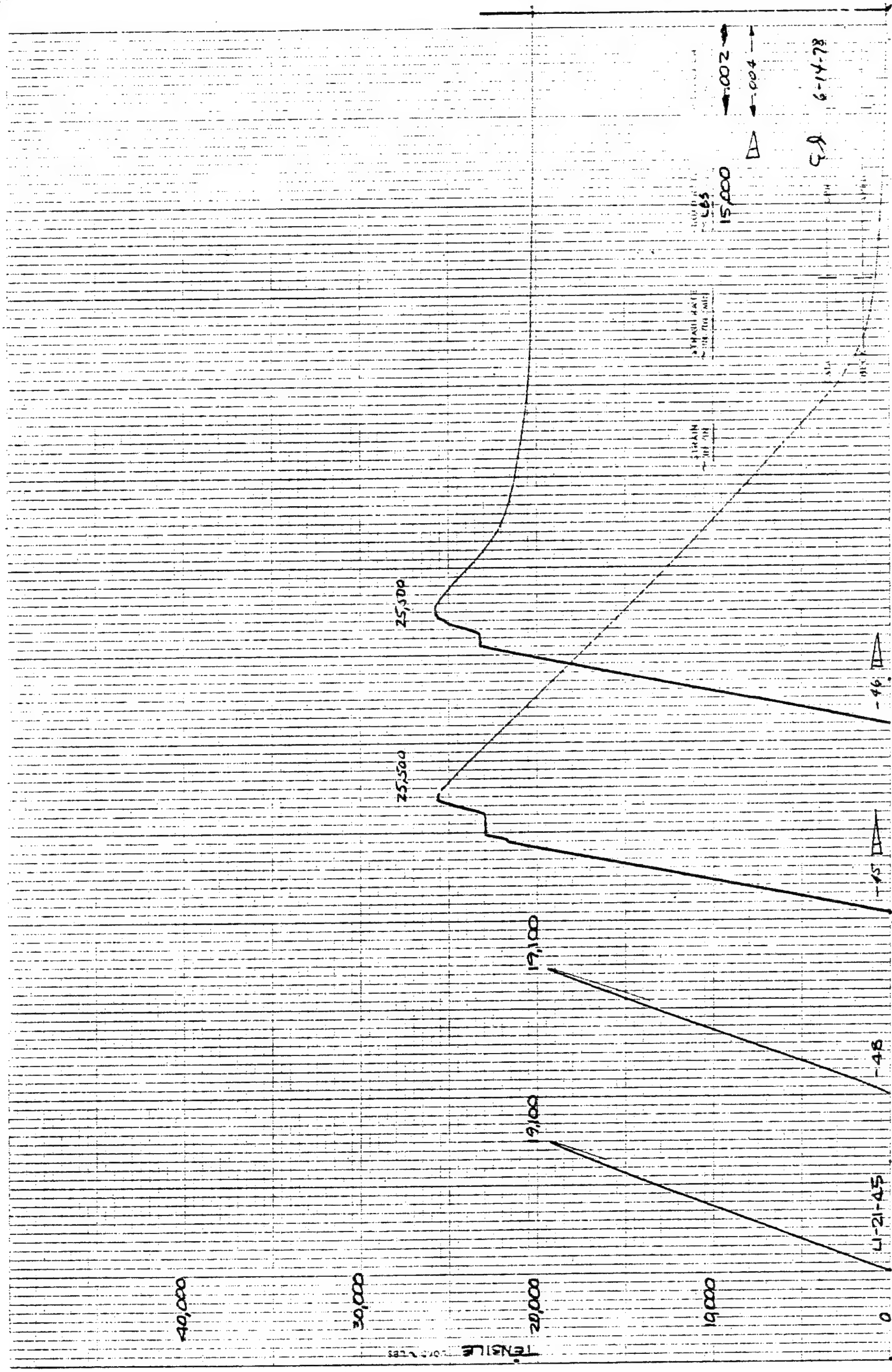
VISUAL DAMAGE

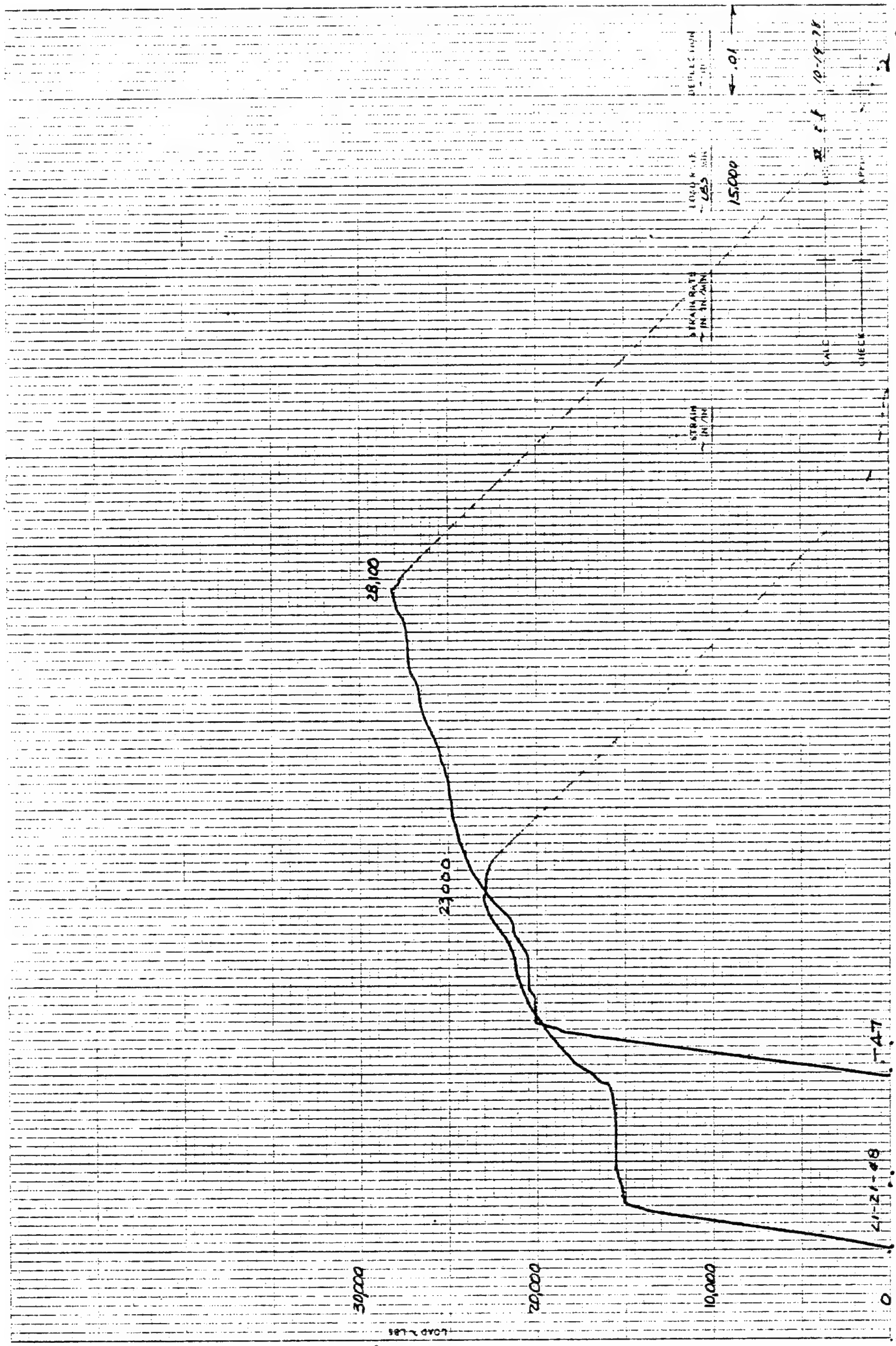
NONE



AFTER MOISTURE CONDITIONING




LI-21-45
19,100
-48
19,100
-45
25,500
-46
25,500
15,000
LBS
.002
.004
6-14-78
40,000
30,000
20,000
10,000
0
TENSILE


28,100
23,000
T-4-7
30,000
20,000
10,000
0
LOAD ~ LBS
DEFLECTION ~ IN
.01
15,000
STRAIN RATE ~ IN/IN/MIN
STRAIN ~ IN/IN
10-19-78
CALC
CHECK

LAMINATE L1

3/8 HP HOLE

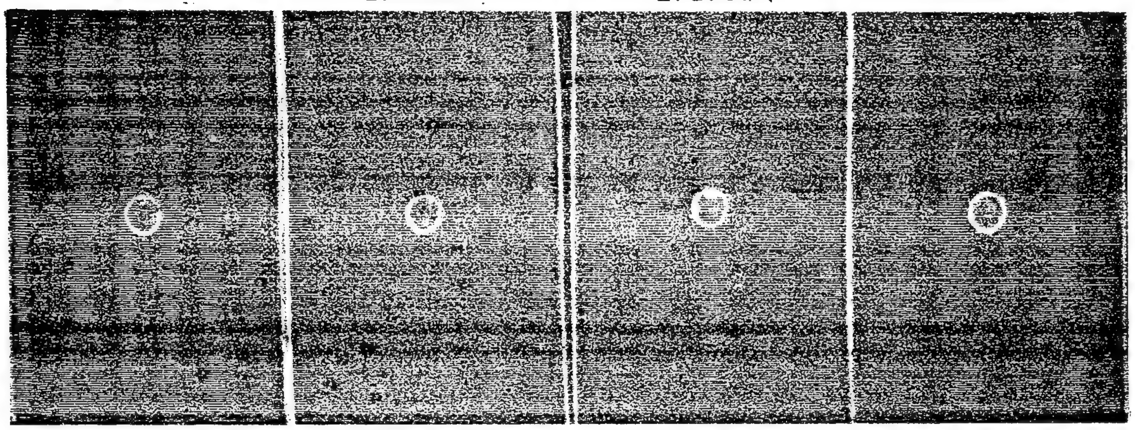
TEST SPECIMENS

ROOM TEMPERATURE

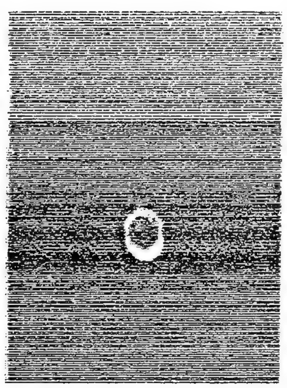
422° K (300° F)

L1-21-49 L1-21-50 L1-21-51 L1-21-52

INITIAL



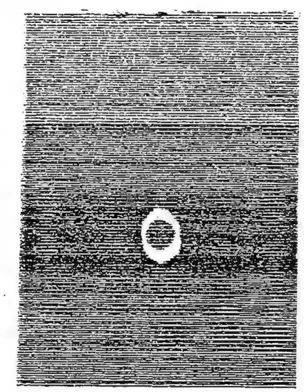
AFTER PRELOAD 18.3 KIP



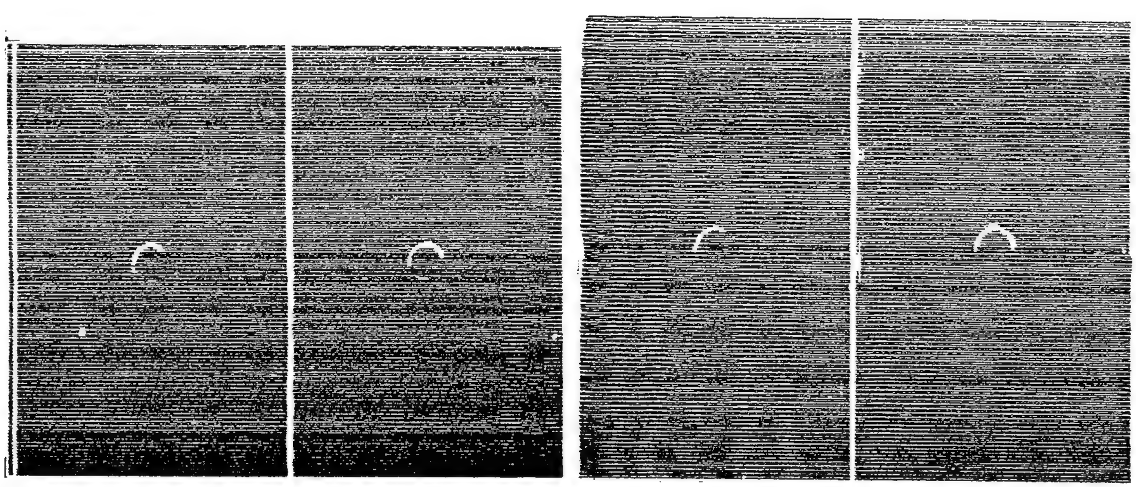
VISUAL DAMAGE

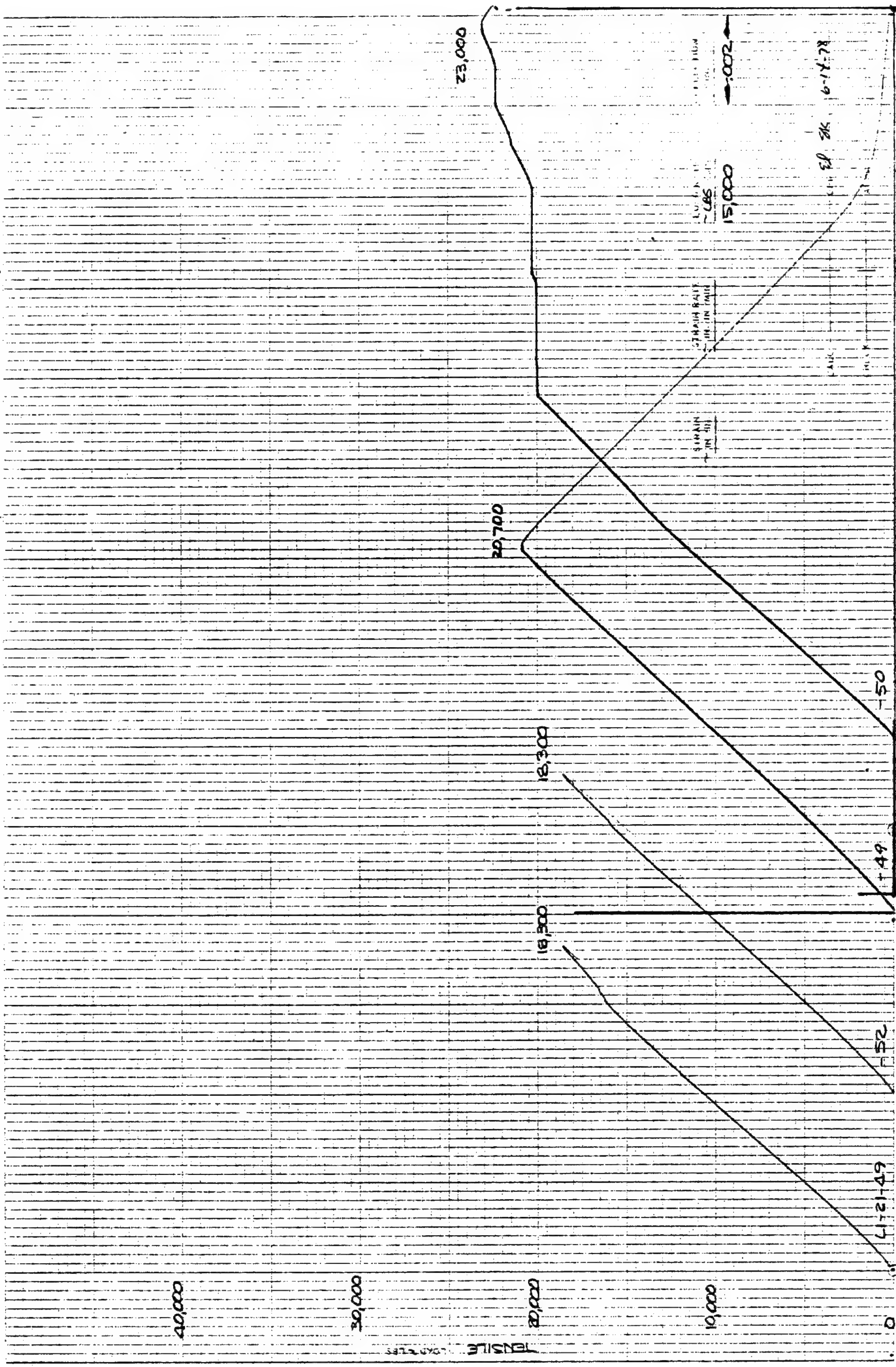
FINE CRACK

NONE

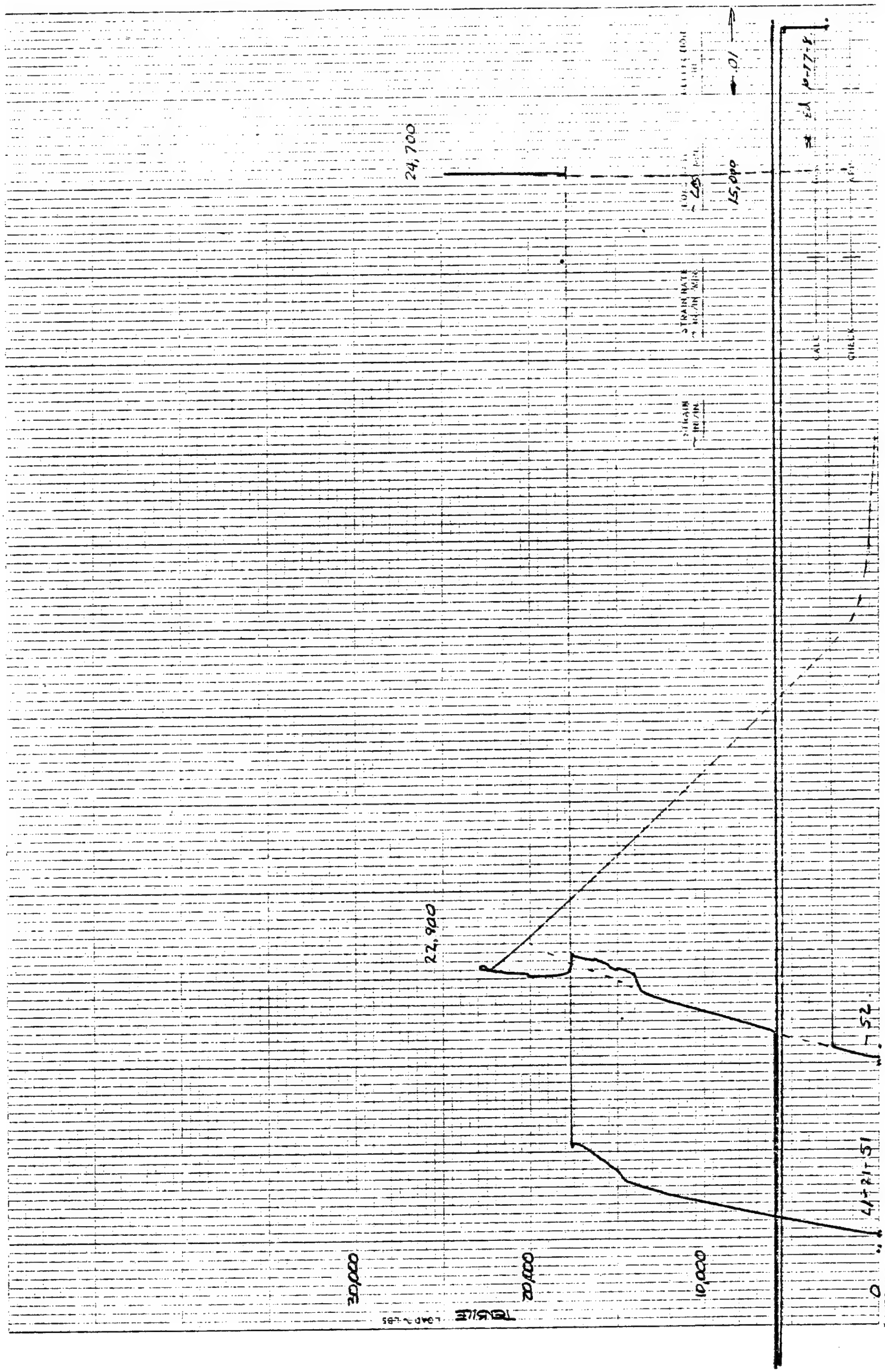


AFTER MOISTURE CONDITIONING





TENSILE LOAD LBS
0
10,000
20,000
30,000
40,000
41-21-49
18,300
18,300
+49
-50
-52
20,700
23,000
15,000
.002
6-14-78


24,700
22,900
30,000
20,000
10,000
0
15,000
TENSILE LOAD LBS
STRAIN RATE
STRAIN
CALL
CHECK
52
41-2-1T-51

LAMINATE L1

3/8 HP SLIT

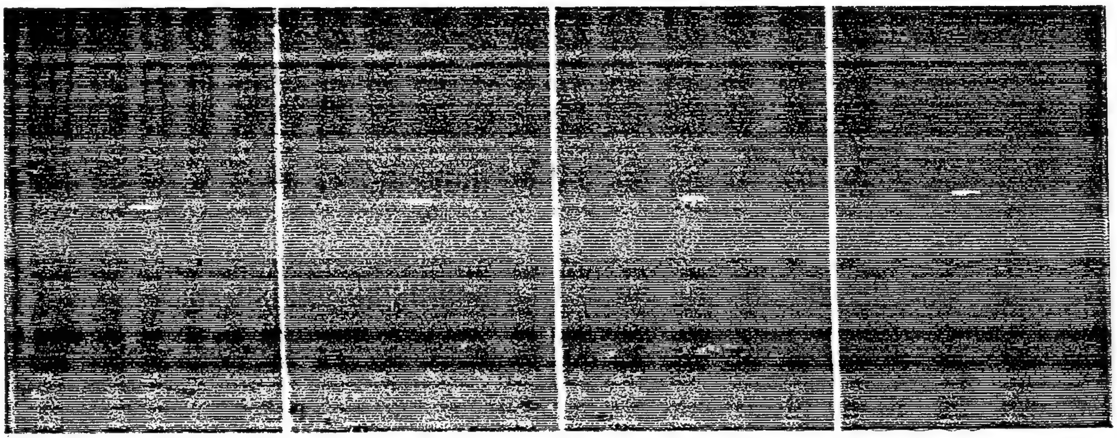
TEST SPECIMENS

ROOM TEMPERATURE

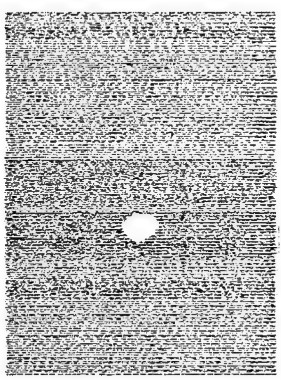
422° K (300° F)

L1-21-53 L1-21-54 L1-21-55 L1-21-56

INITIAL

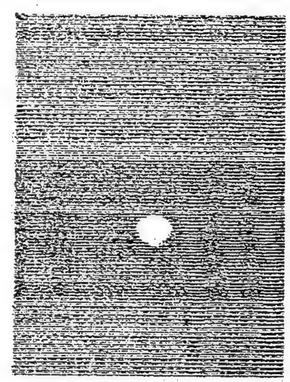


AFTER
PRELOAD
17.3 KIP

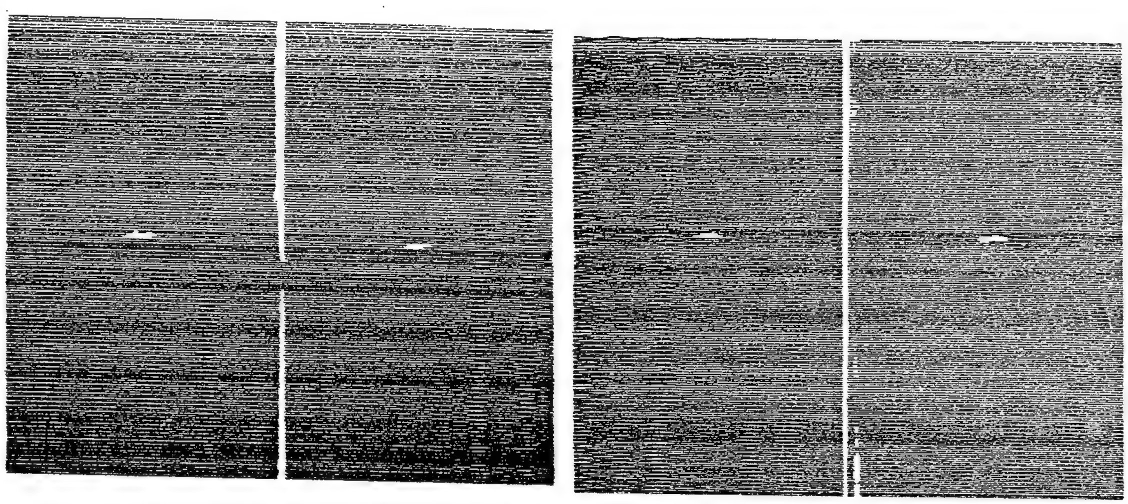


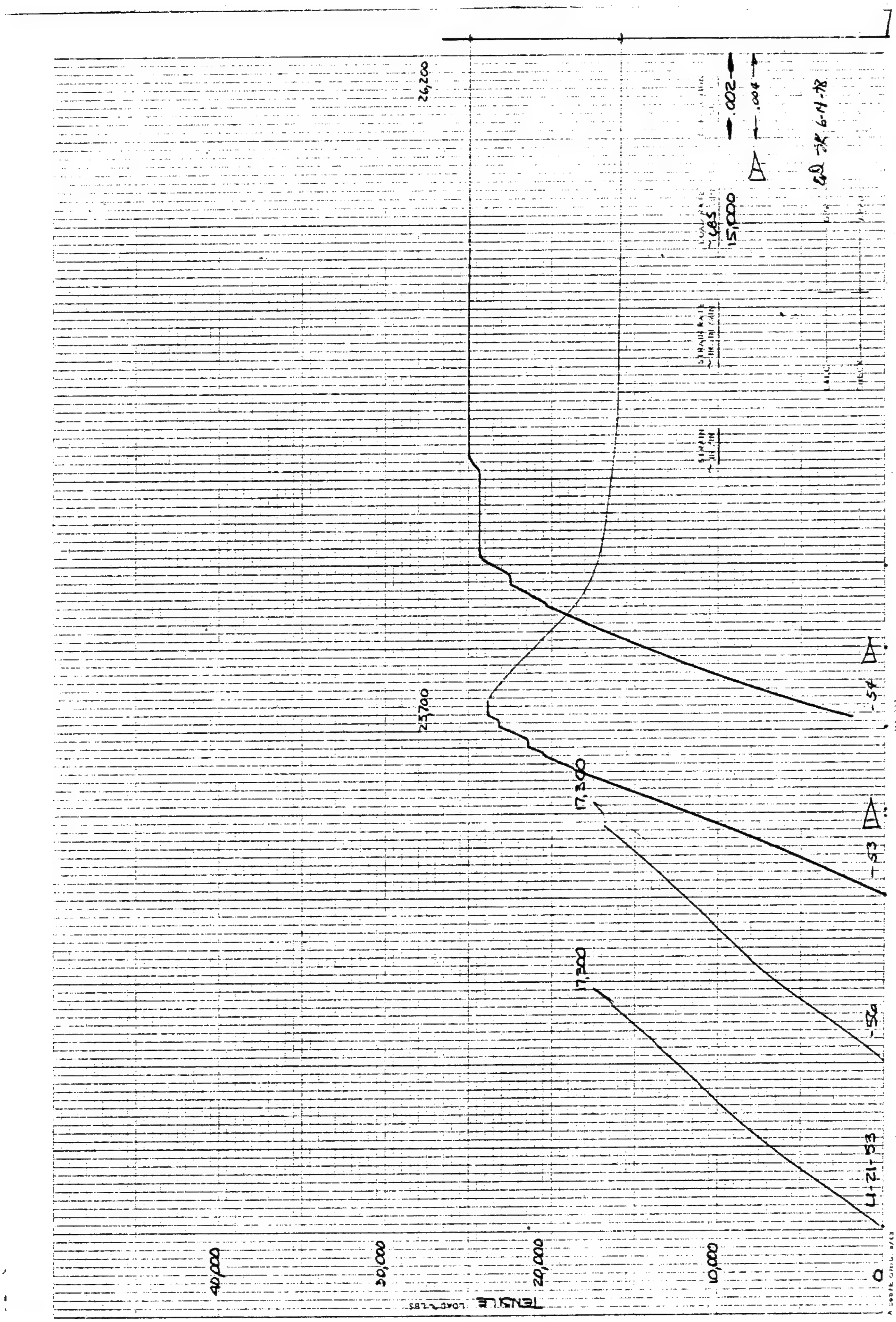
VISUAL DAMAGE

← NONE →

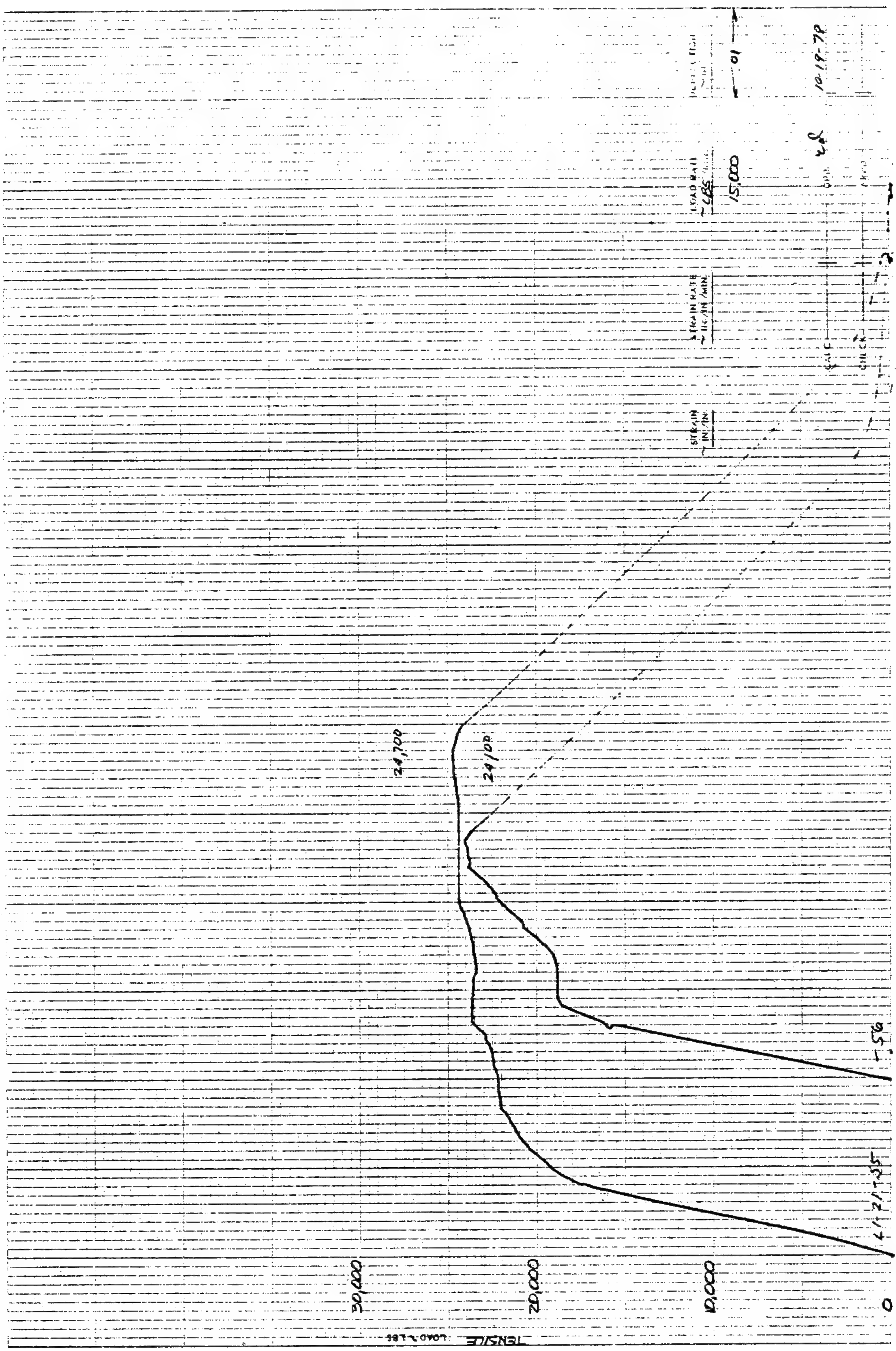


AFTER
MOISTURE
CONDITIONING





TENSILE LOAD ~LBS
40,000
30,000
20,000
10,000
0
26,200
23,700
17,300
17,300
4-21-53
-53a
-53
-54
.002
.004
15,000
6-14-78


TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
24,700
24,100
LOAD RATE ~ LBS/MIN
15,000
STRAIN RATE ~ IN/IN/MIN
STRAIN ~ IN/IN
10-19-78

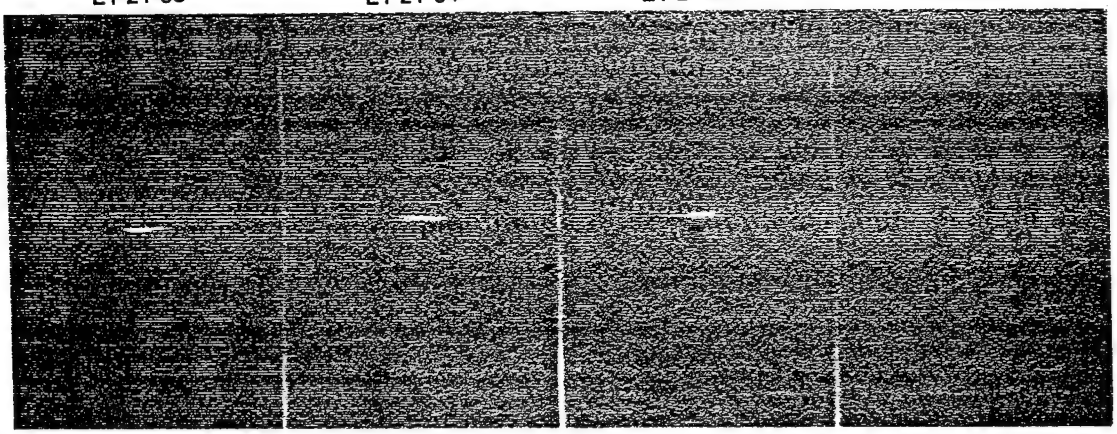
LAMINATE L1
5/8 HP SLIT

TEST SPECIMENS

ROOM TEMPERATURE | 422° K (300° F)

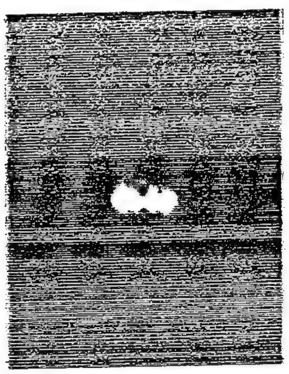
L1-21-63 | L1-21-64 | L1-21-65 | L1-21-66

INITIAL

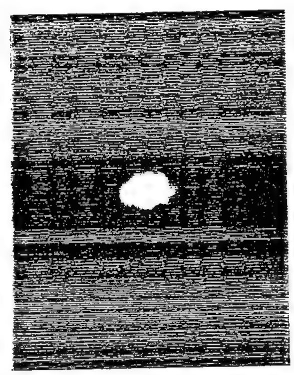


VISUAL DAMAGE

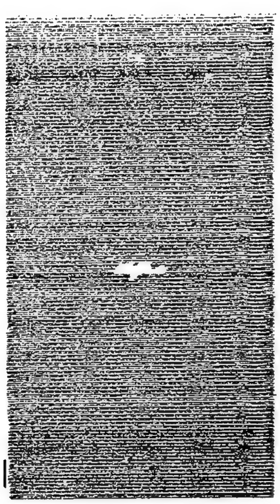
AFTER PRELOAD 17.7 KIP

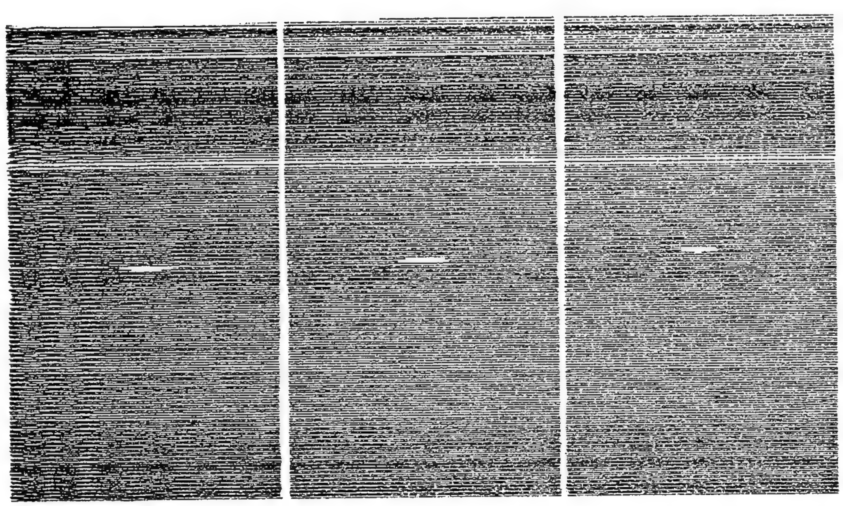


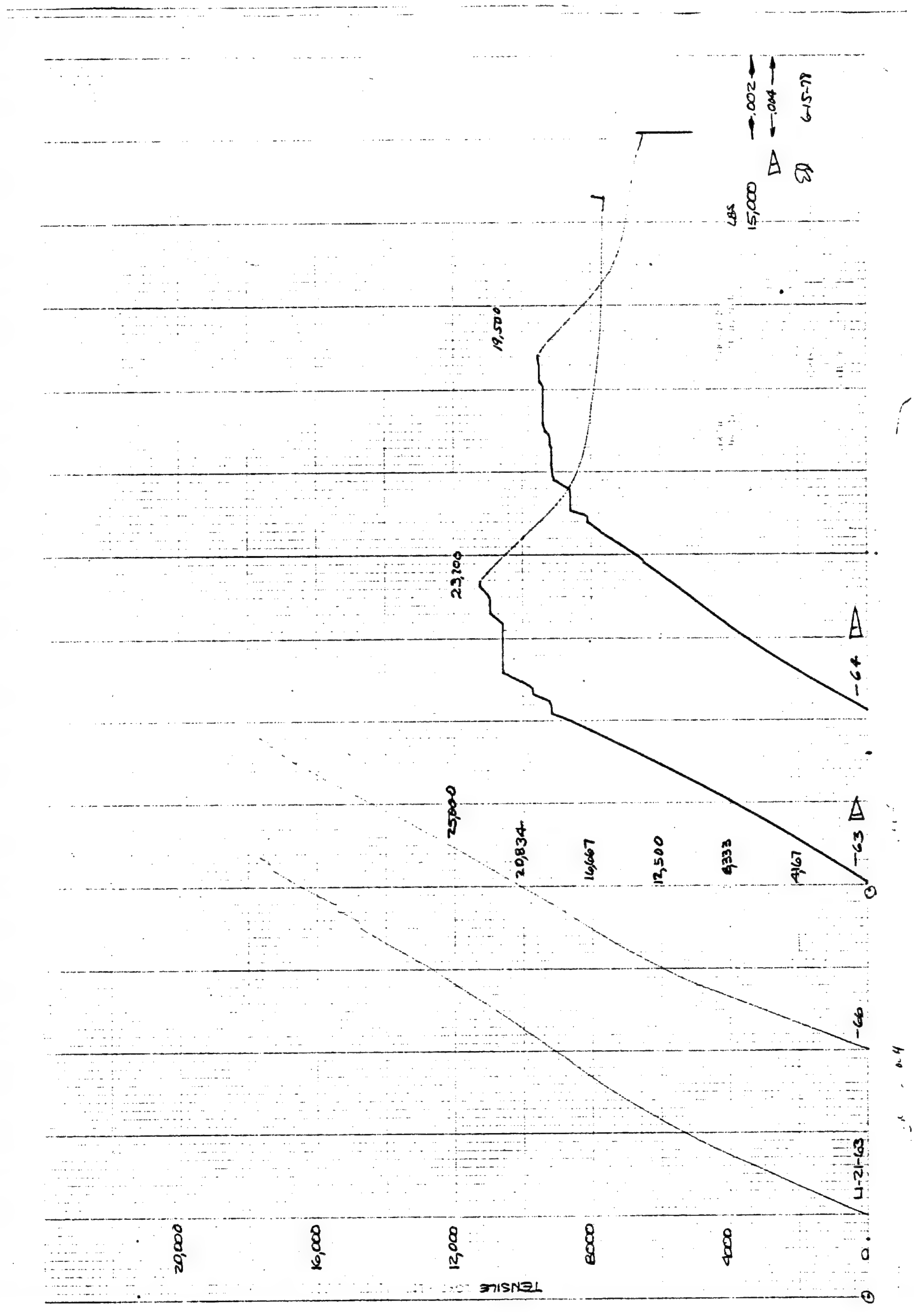
FINE CRACKS



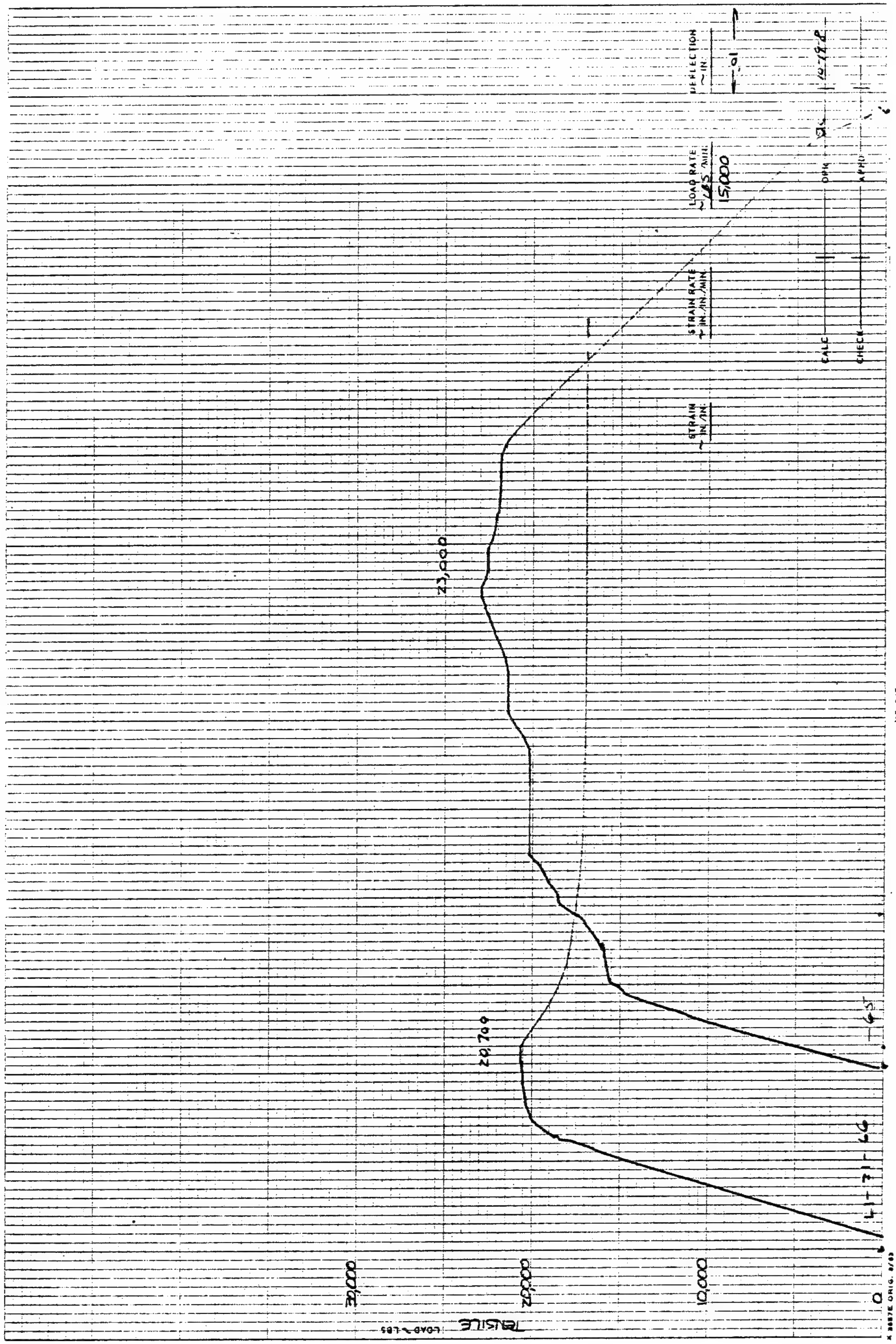
AFTER MOISTURE CONDITIONING







TENSILE
20,000
16,000
12,000
8000
4000
0
4-21-63
-66
-63
-64
4167
8333
12,500
16,667
20,834
25,000
23,200
19,500
LBS
15,000
.002
.004
6-15-79


TENSILE LOAD ~ LBS
0
10,000
20,000
30,000
20,700
23,000
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE ~ LBS/MIN.
15,000
DEFLECTION ~ IN.
.01
CALC
CHECK

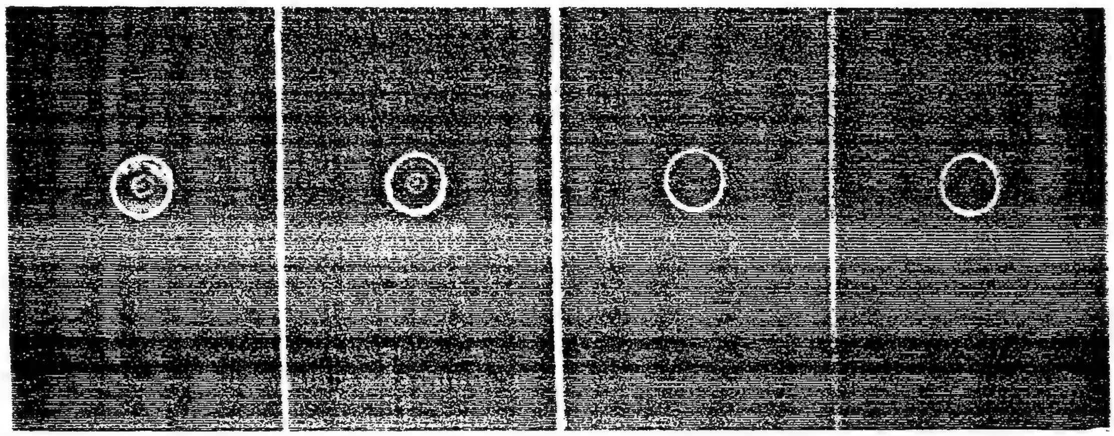
LAMINATE L1
5/8 HP HOLE

TEST SPECIMENS

ROOM TEMPERATURE | 422° K (300° F)

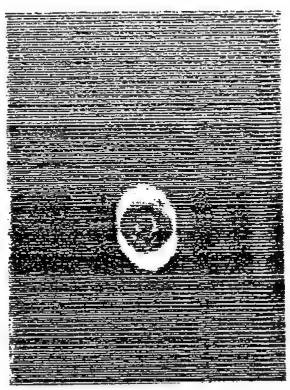
L1-21-59 | L1-21-61 | L1-21-62 | L1-21-67

INITIAL



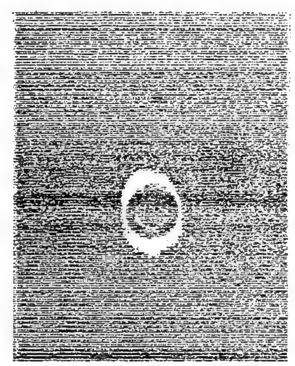
VISUAL DAMAGE

AFTER
PRELOAD
16.1 KIP

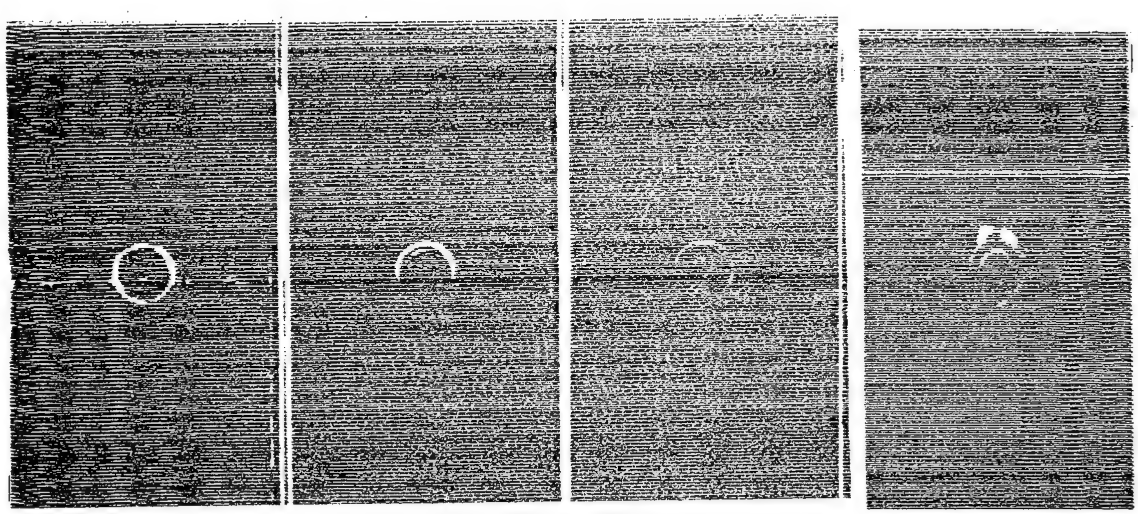


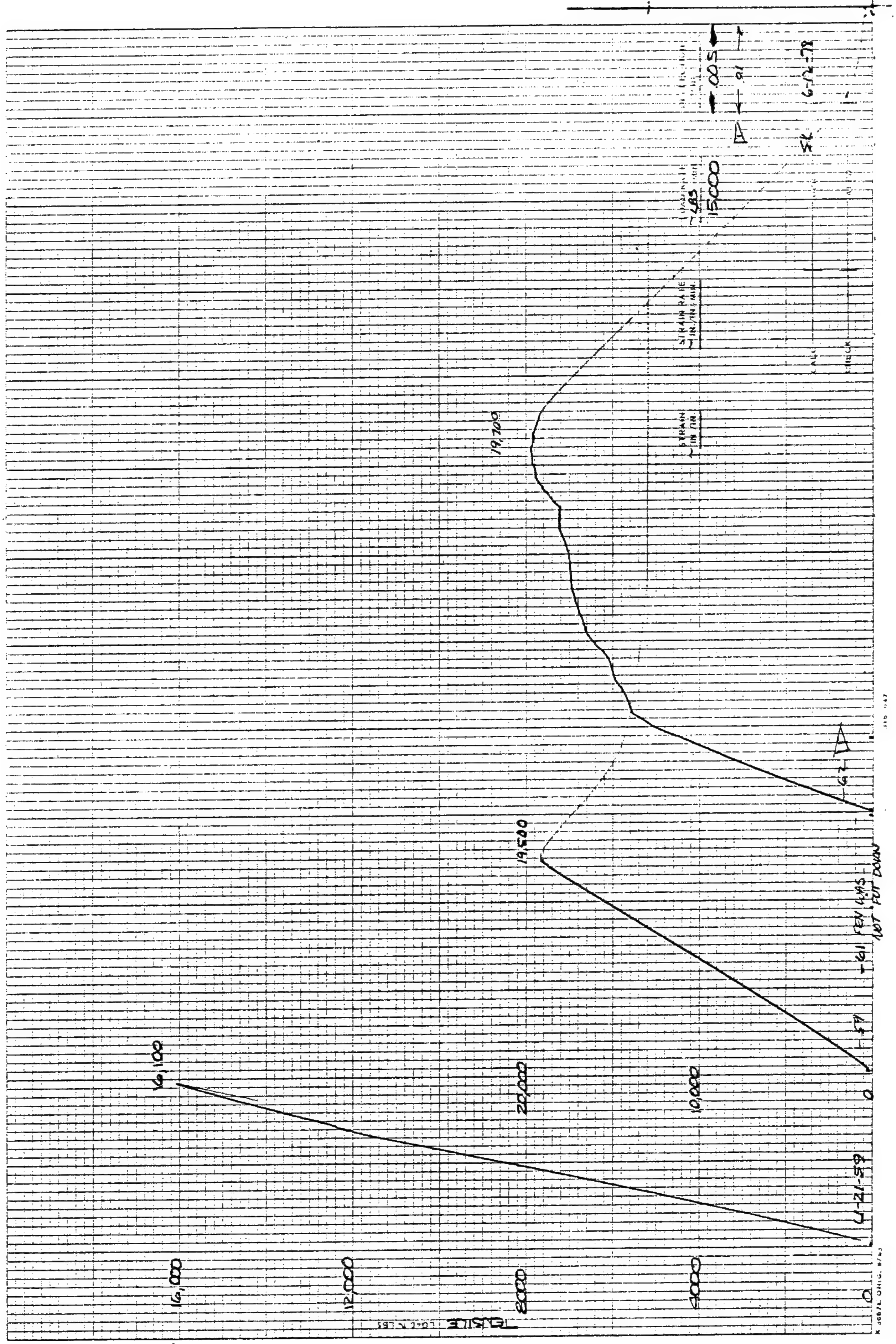
← NONE

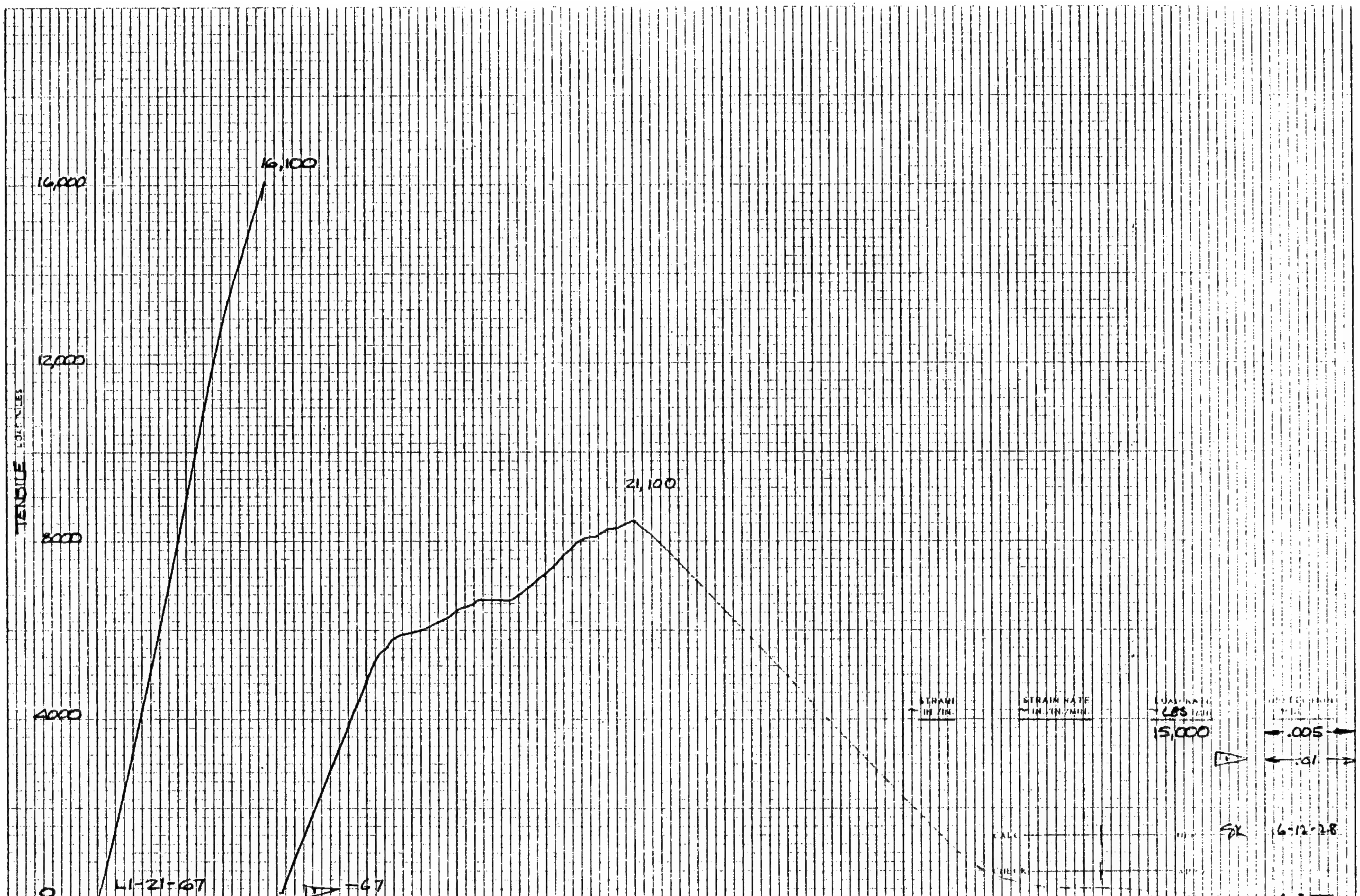
FINE CRACK 0.1 inch →



AFTER
MOISTURE
CONDITIONING




16,000
12,000
8000
4000
0
16,100
20,000
10,000
0
19,500
19,200
15000
6-21-59
6-12-78
.005
STRAIN RATE ~IN/IN/MIN
STRAIN ~IN/IN
TENSILE LOAD LBS


16,100
21,100
16,000
12,000
8000
4000
0
TENSILE
LOAD
L1-21-67
T-67
STRAIN IN./IN.
STRAIN RATE IN./IN./MIN.
LOAD RATE LBS
15,000
.005
.01
SK
6-12-28

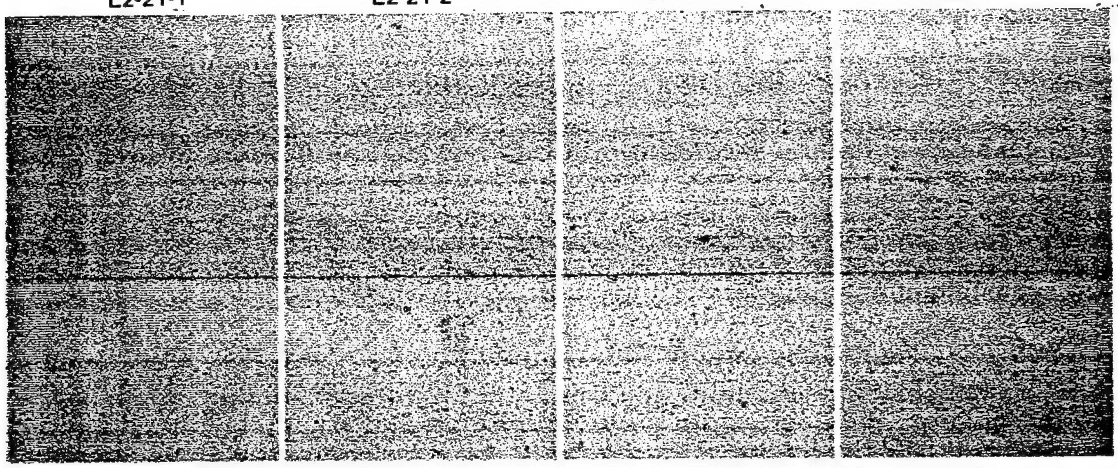
LAMINATE L2
NO DEFECT

TEST SPECIMENS

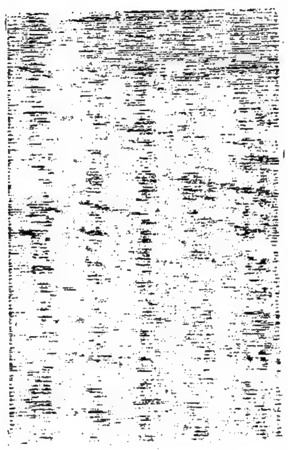
ROOM TEMPERATURE | 422° K (300° F)

L2-21-1 | L2-21-2 | L2-21-3 | L2-21-4

INITIAL

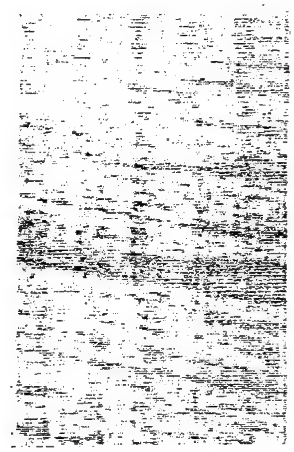


AFTER PRELOAD 35.1 KIP

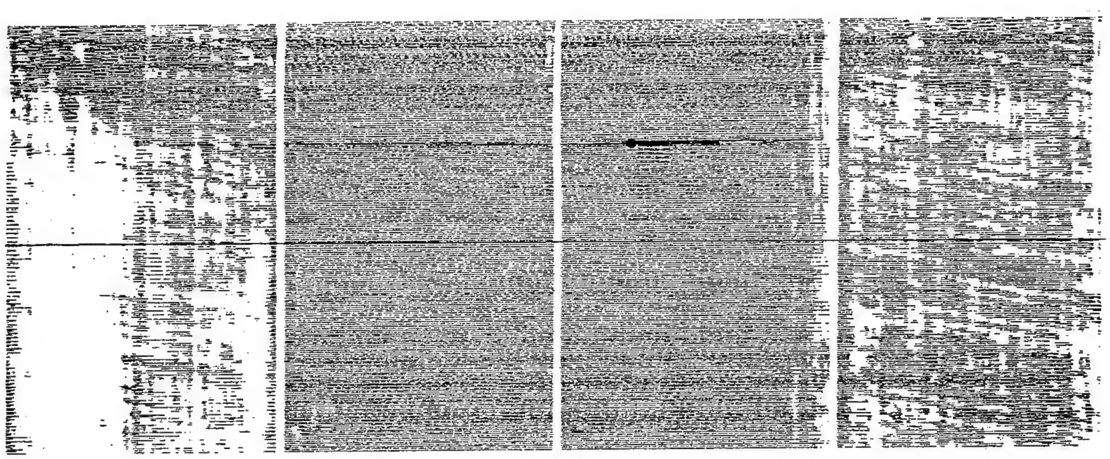


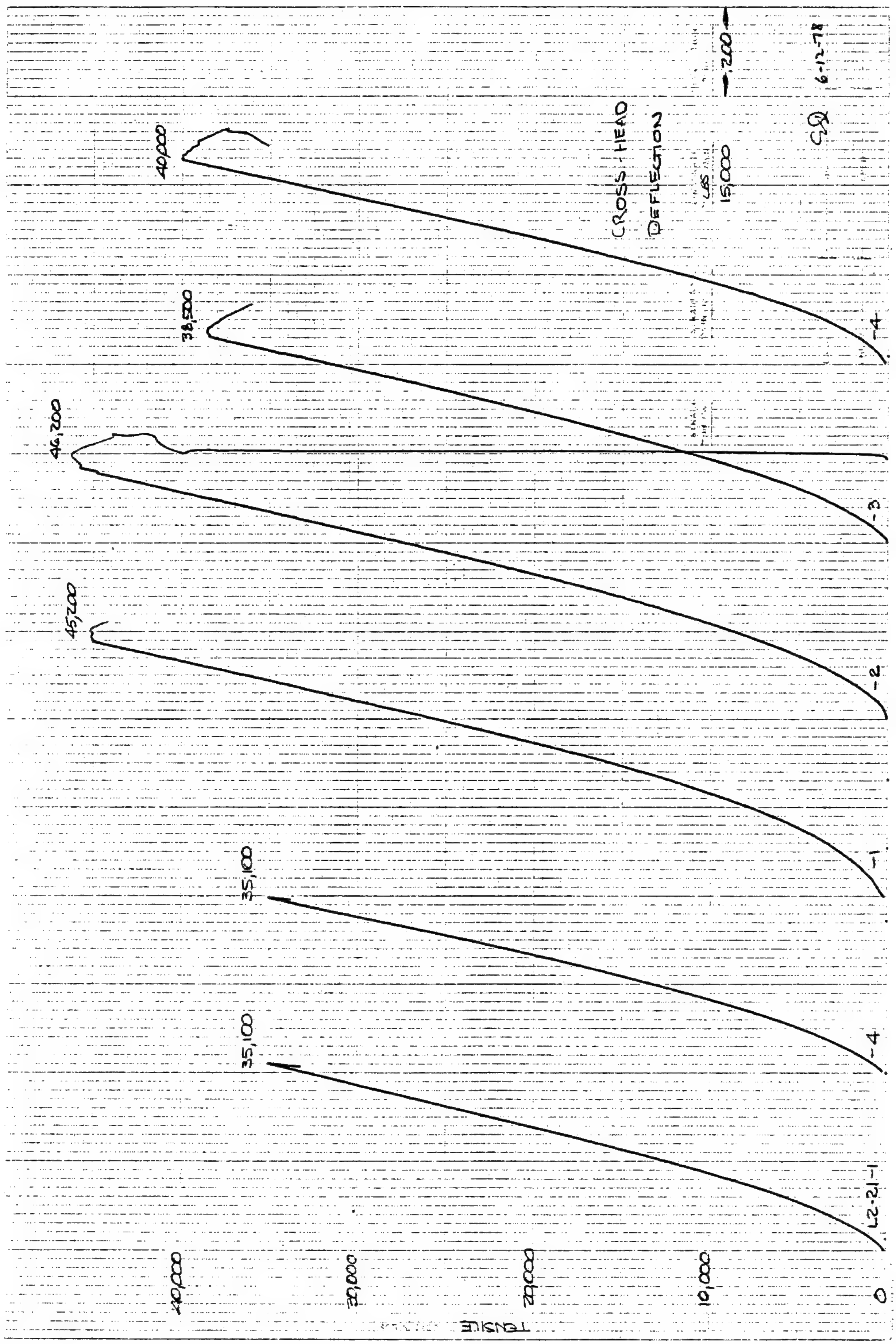
VISUAL DAMAGE

← NONE →

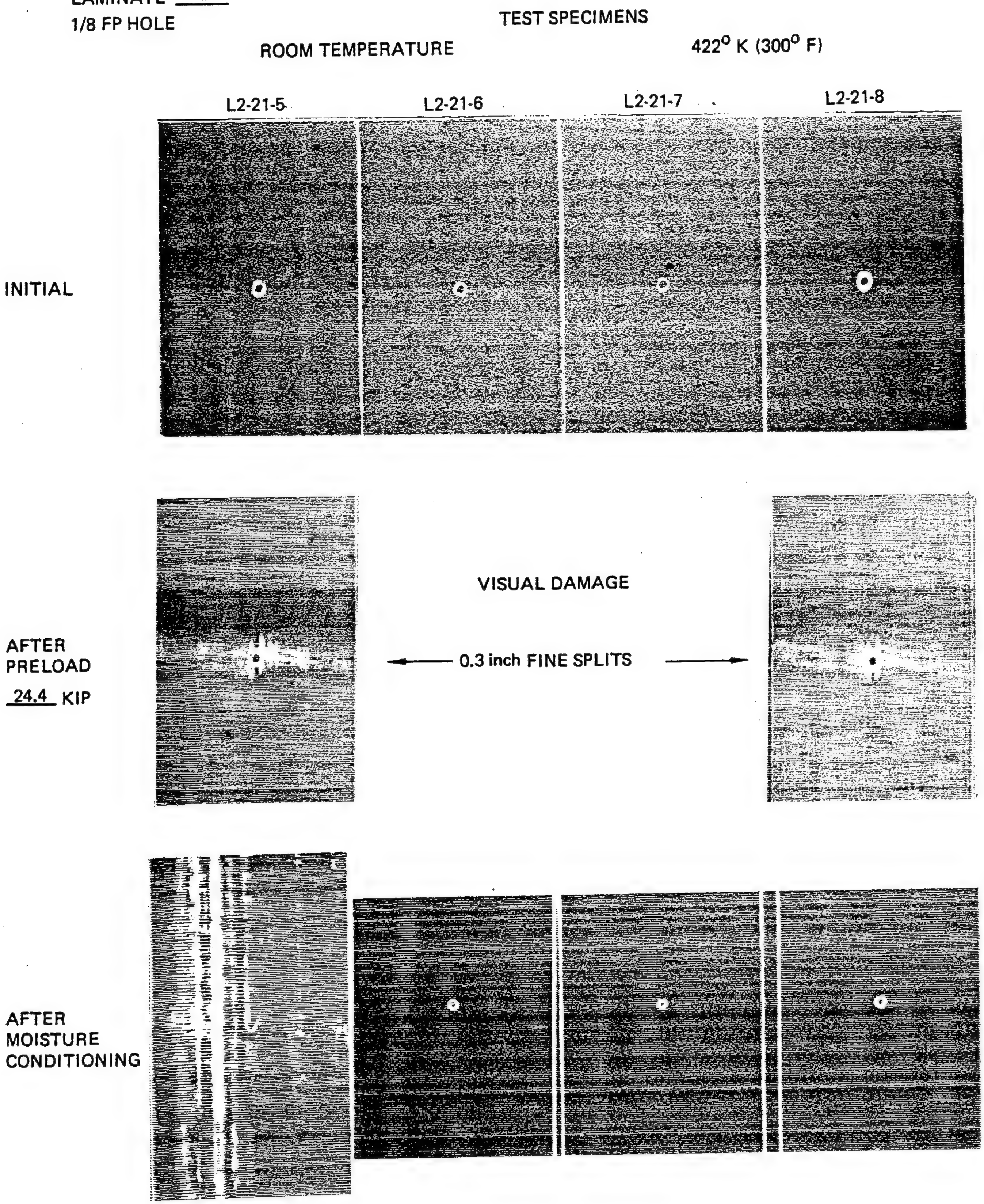


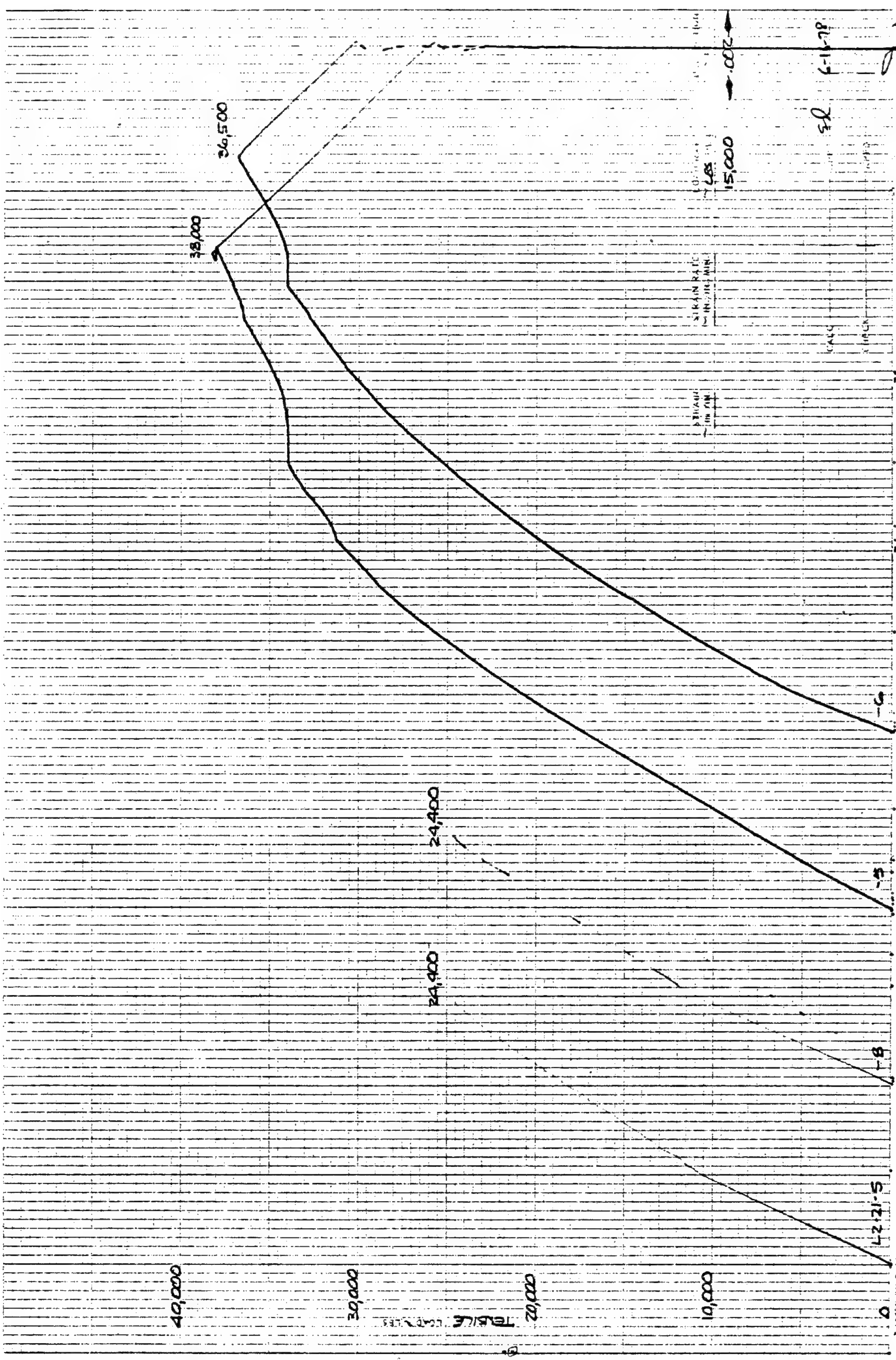
AFTER MOISTURE CONDITIONING

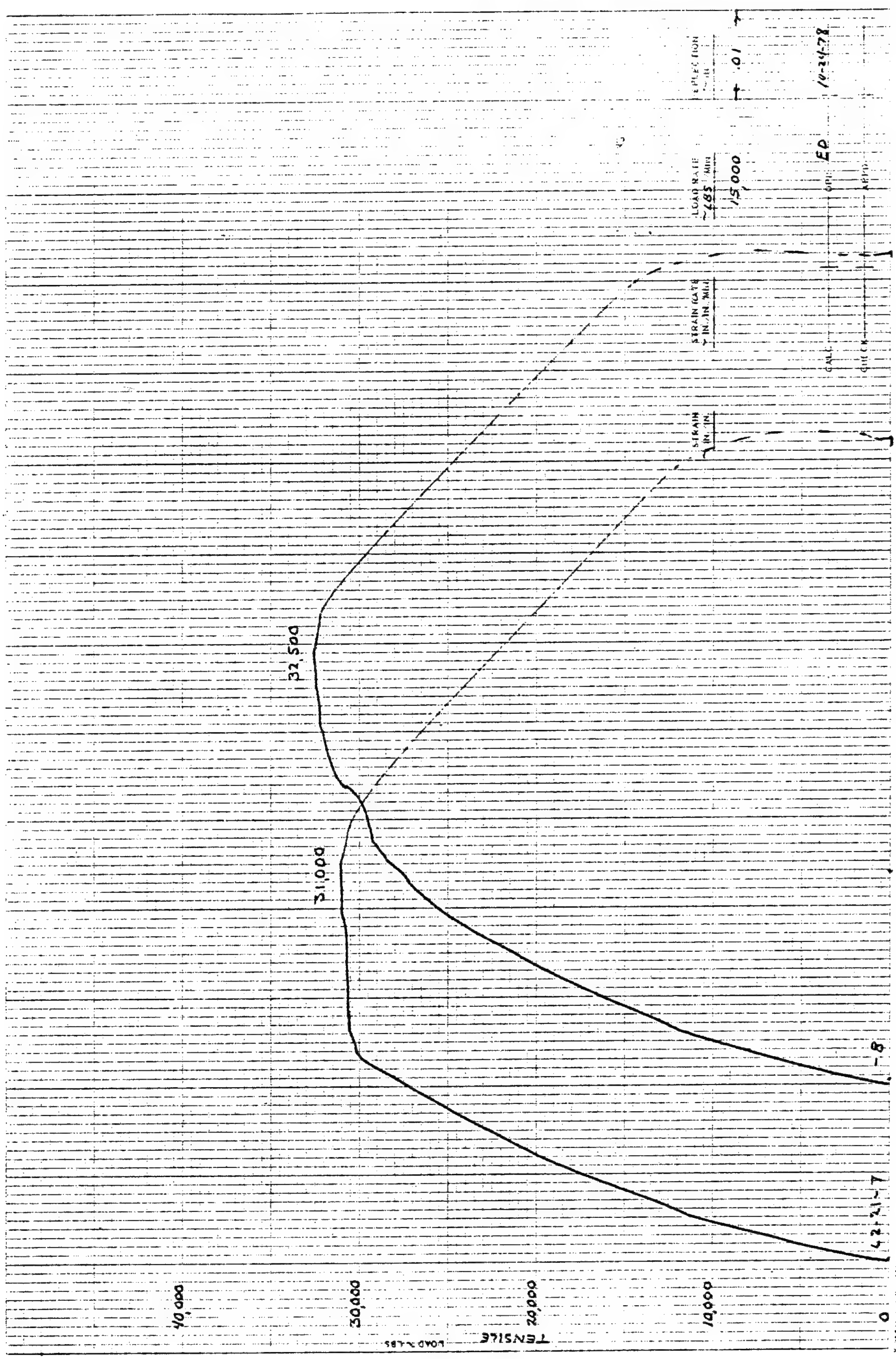



L2-21-1
-4
-1
-2
-3
-4
35,100
35,100
45,200
46,200
38,500
40,000
CROSS-HEAD
DEFLECTION
LBS
15,000
.200
6-12-78
0
10,000
20,000
30,000
40,000
TENSILE

LAMINATE L2
1/8 FP HOLE




36,500
38,000
24,400
24,400
15,000
LBS
.002
6-1-78
L221-5
-8
-3
-6
40,000
30,000
20,000
10,000
0
TENSILE LOAD, LBS



TENSILE
LOAD - LBS
40,000
30,000
20,000
10,000
0
32,500
31,000
42-21-7
1-8
LOAD RATE
15,000
DEFLECTION
.01
STRAIN RATE
STRAIN
ED
10-24-78

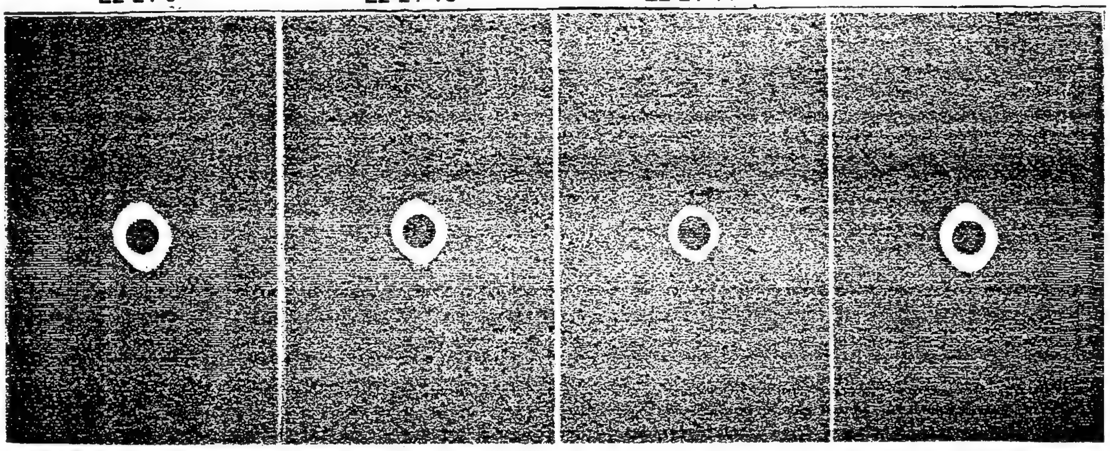
LAMINATE L2
3/8 FP HOLE

TEST SPECIMENS

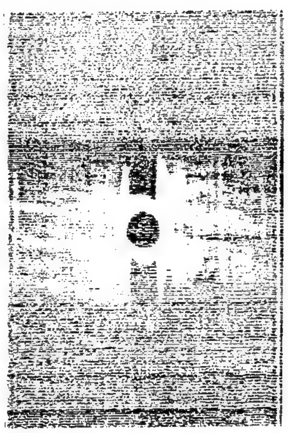
ROOM TEMPERATURE | 422° K (300° F)

L2-21-9 | L2-21-10 | L2-21-11 | L2-21-12

INITIAL

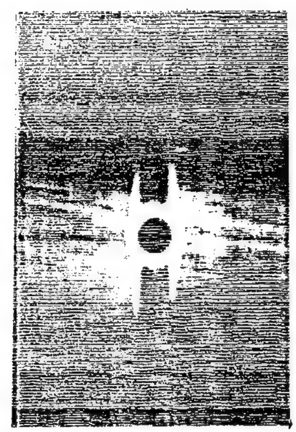


AFTER PRELOAD
22.9 KIP

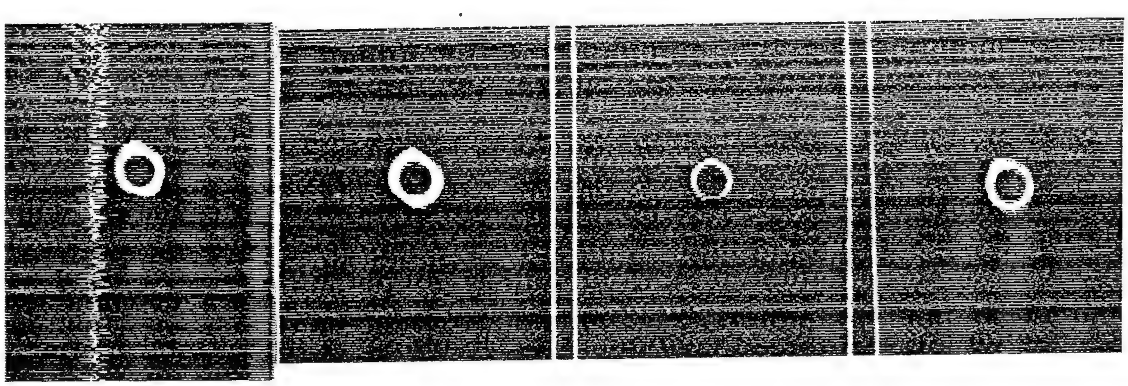


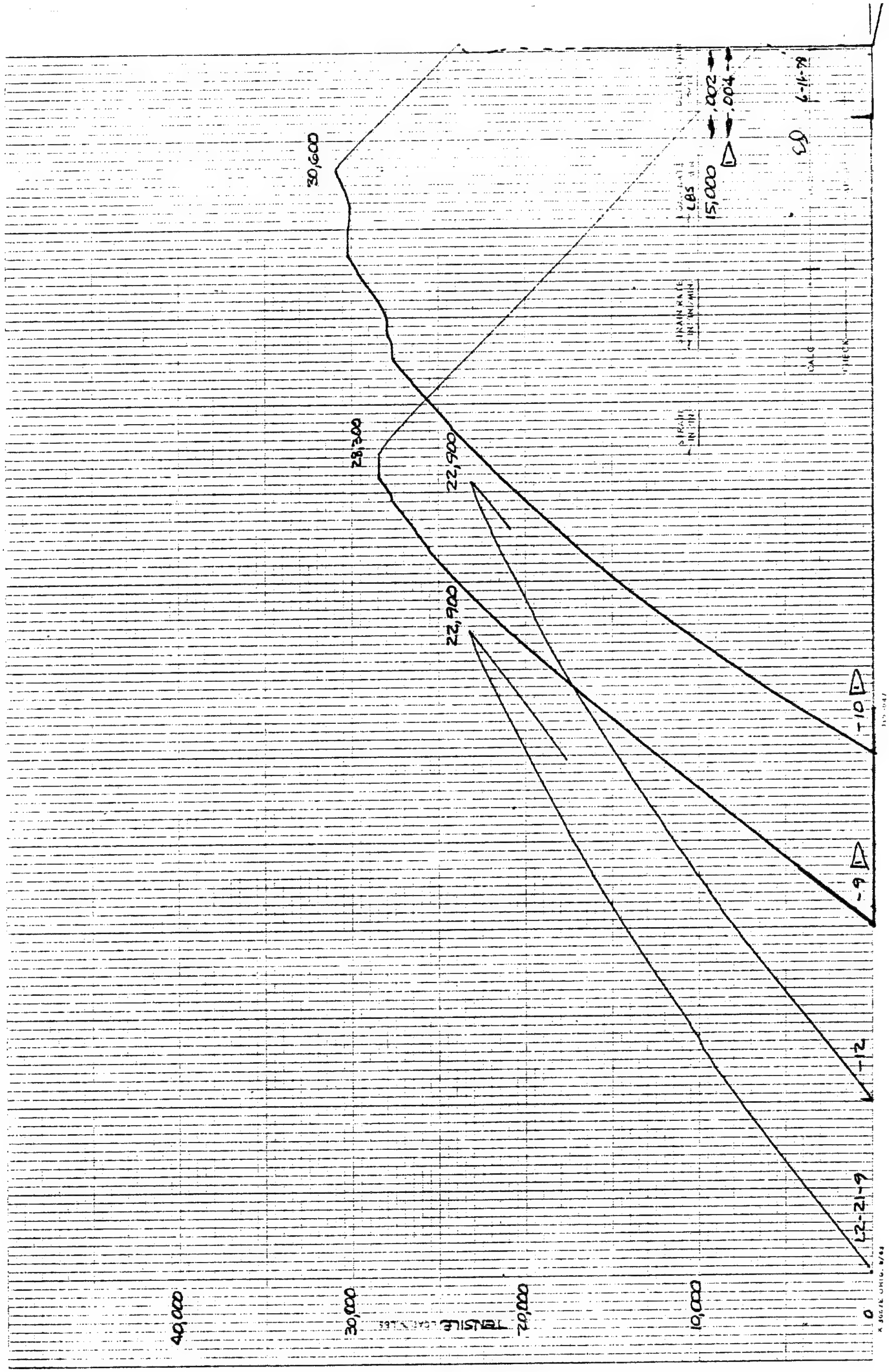
VISUAL DAMAGE

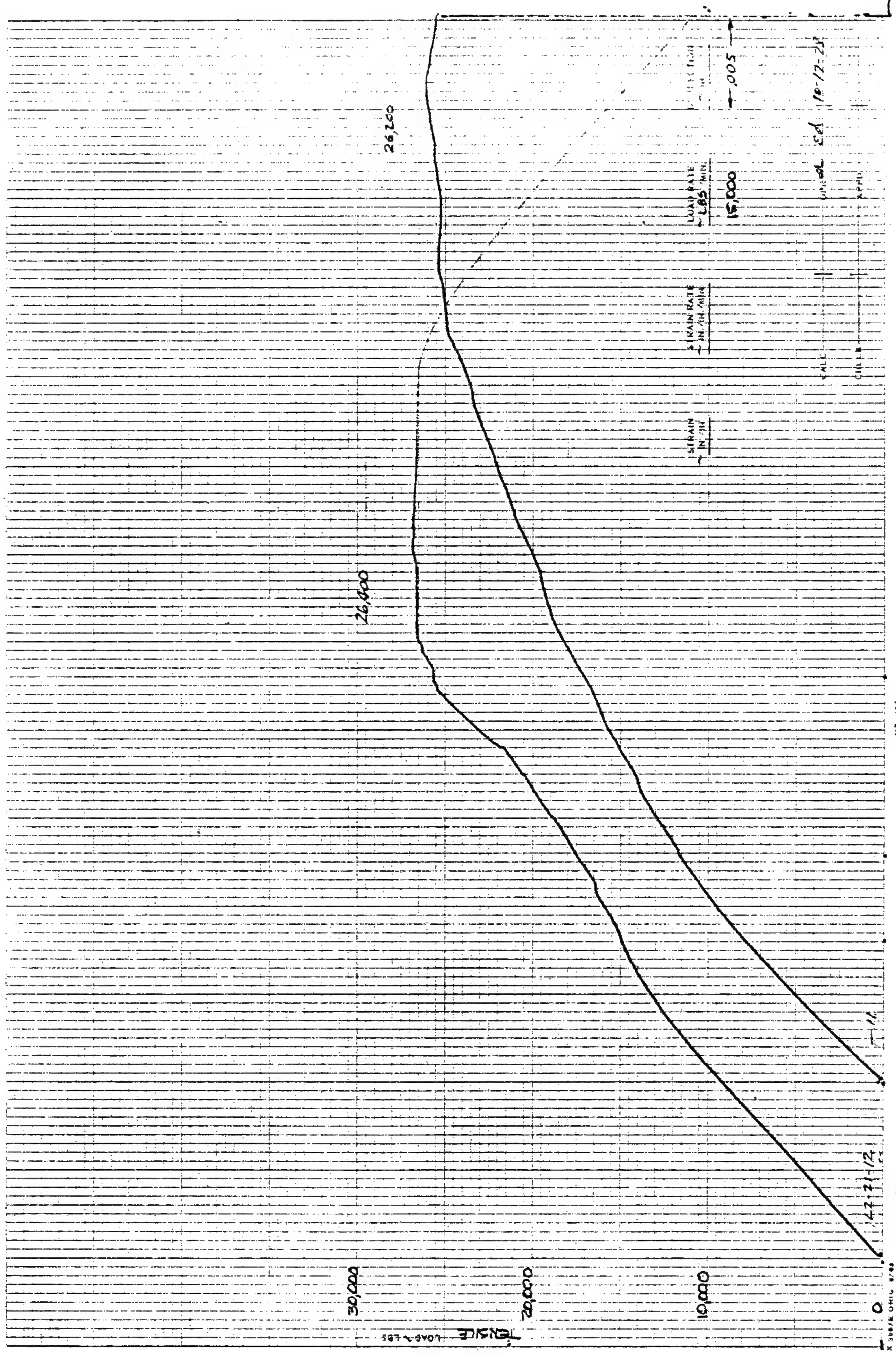
← 1.0 inch FINE SPLITS →



AFTER MOISTURE CONDITIONING




30,600
28,300
22,900
22,900
-10
-9
-12
L2-21-9
6-14-78
LBS
15,000
.002
.004
STRAIN RATE
STRAIN
CALC
CHECK
40,000
30,000
20,000
10,000
0
TENSILE



26,200
26,000
30,000
20,000
10,000
0
TENSILE
LOAD ~ LBS
LOAD RATE ~ LBS/MIN
15,000
STRAIN RATE ~ IN./IN./MIN
STRAIN ~ IN./IN.
.005
300°F

LAMINATE L2
5/8 FP HOLE

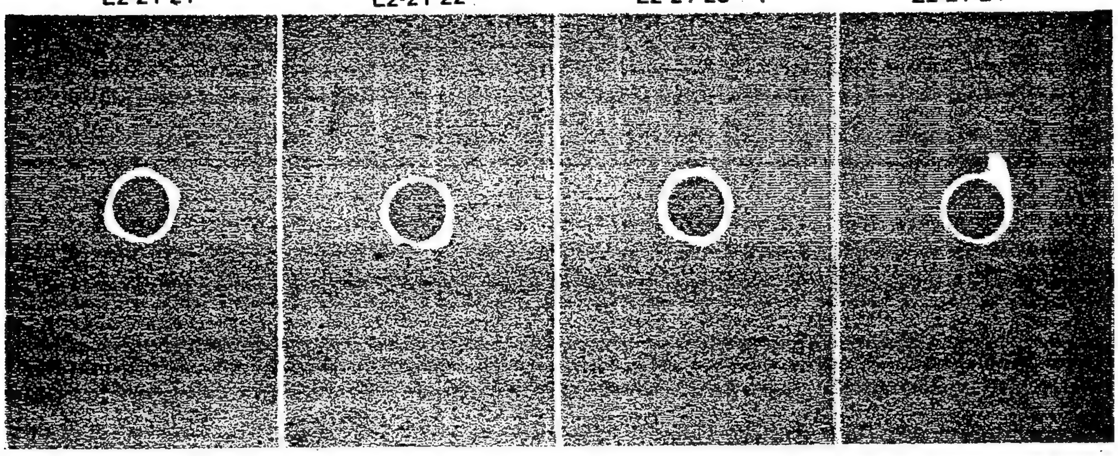
TEST SPECIMENS

ROOM TEMPERATURE

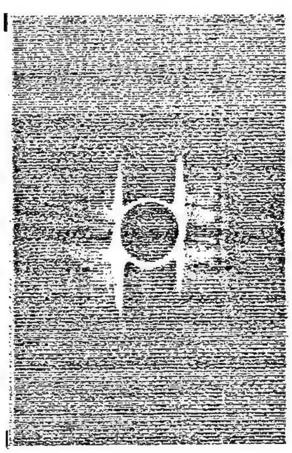
422° K (300° F)

L2-21-21 L2-21-22 L2-21-23 L2-21-24

INITIAL

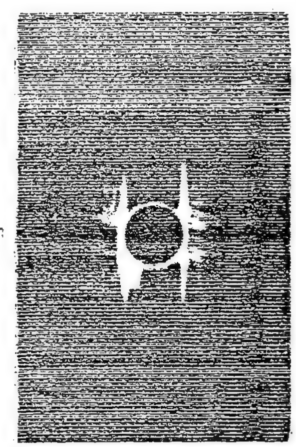


AFTER PRELOAD
17.7 KIP

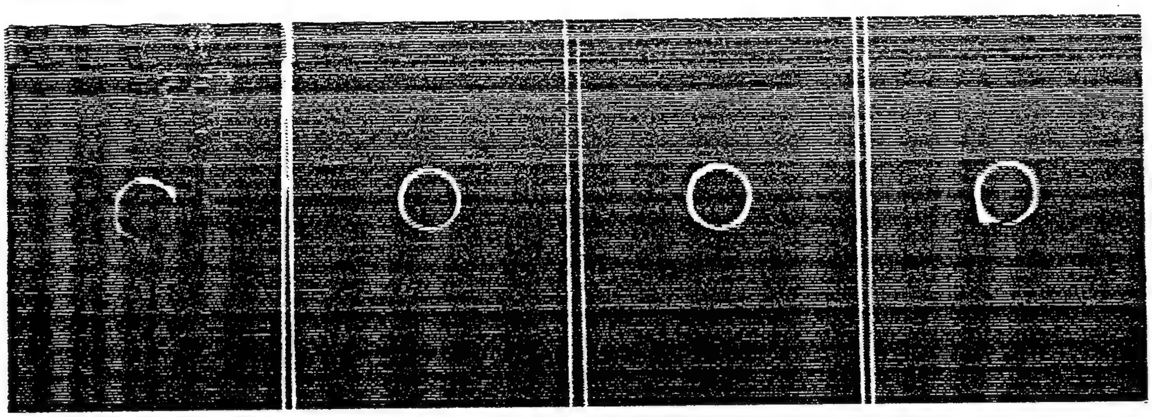


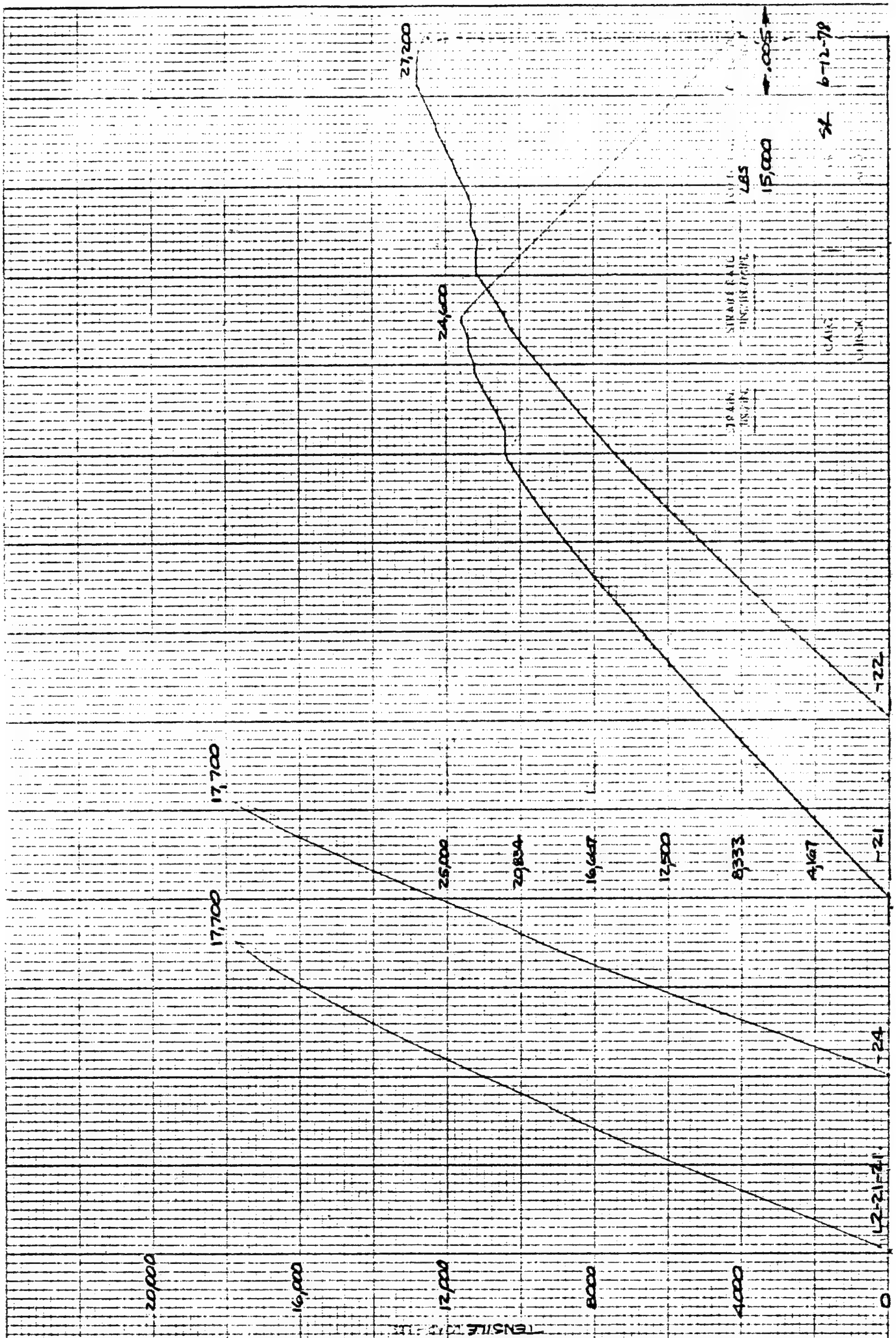
VISUAL DAMAGE

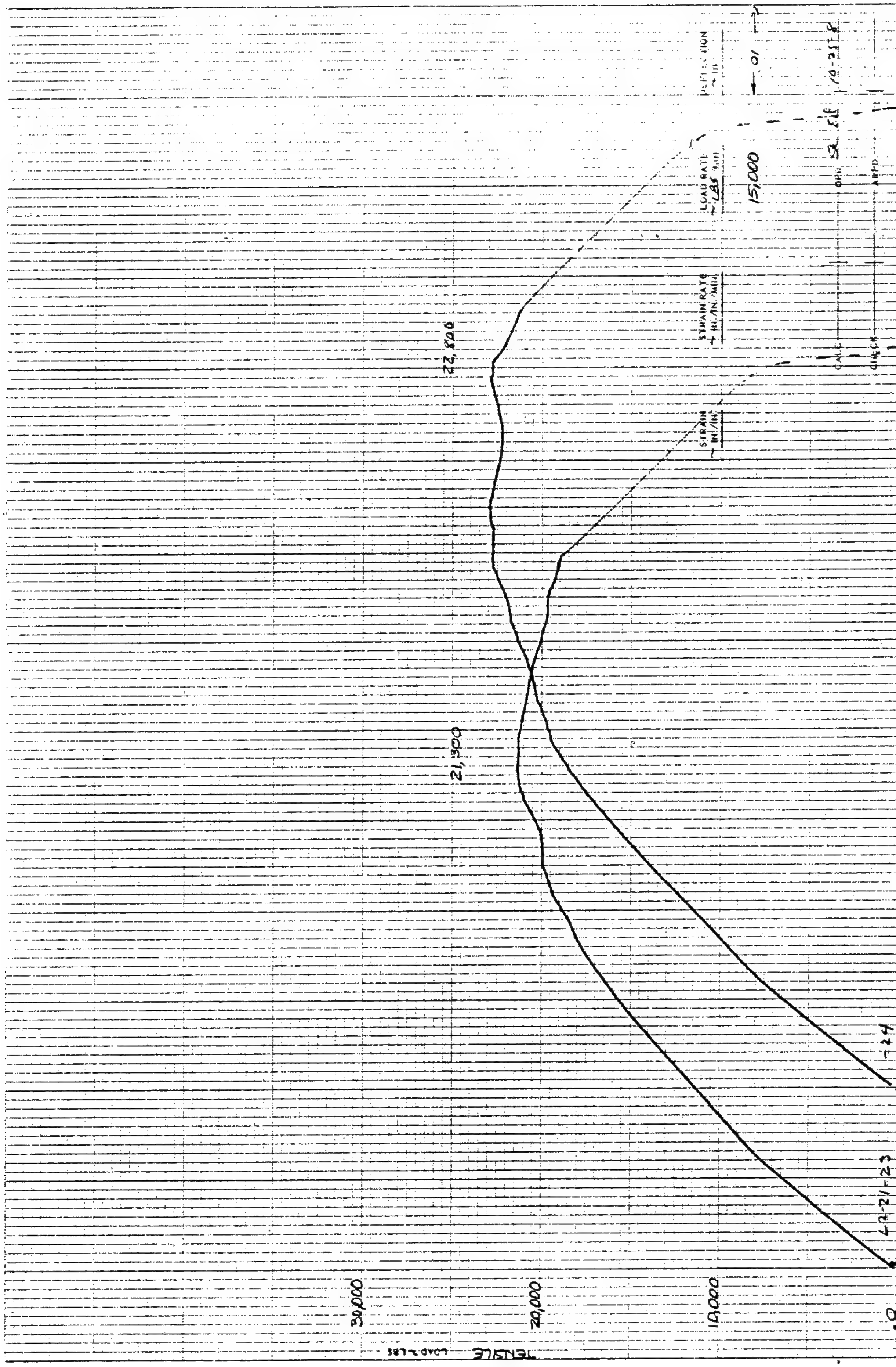
← 1.0 inch FINE SPLITS →



AFTER MOISTURE CONDITIONING




27,200
24,600
17,700
17,700
25,000
20,834
16,667
12,500
8333
4,167
-21
-22
-24
L2-21-21
20,000
16,000
12,000
8000
4000
0
TENSILE LOAD
LBS
15,000
.005
6-12-78


22,800
21,300
15,000
42-21-23
-24
30,000
20,000
10,000
0
TENSILE
LOAD ~ LBS
LOAD RATE ~ LBS/MIN
STRAIN RATE ~ IN/IN/MIN
STRAIN ~ IN/IN

LAMINATE L2

5/8 FP SLIT

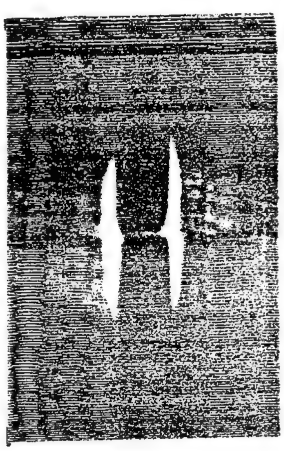
TEST SPECIMENS

ROOM TEMPERATURE | 422° K (300° F)

L2-21-25 | L2-21-26 | L2-21-27 | L2-21-28

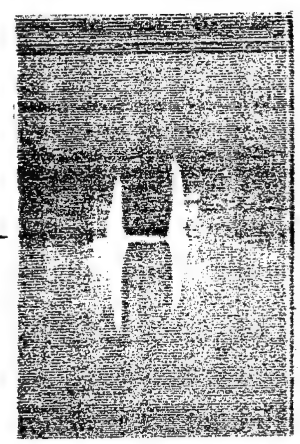
INITIAL

AFTER PRELOAD 19.5 KIP

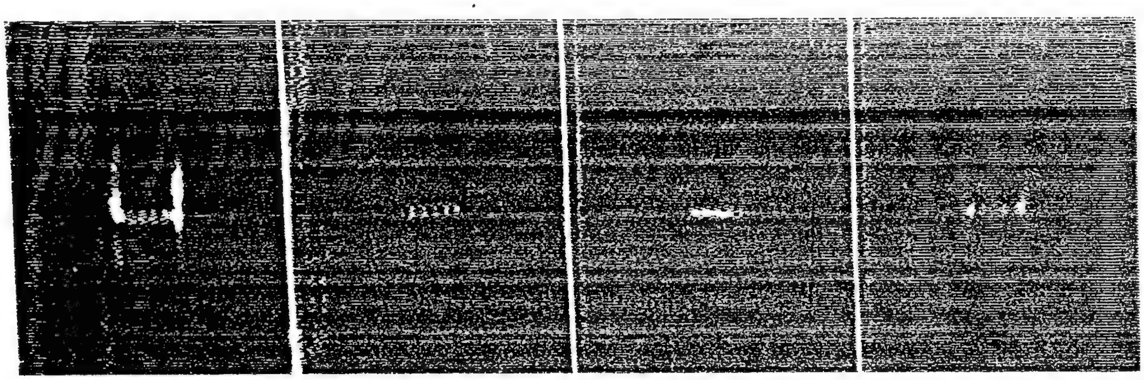


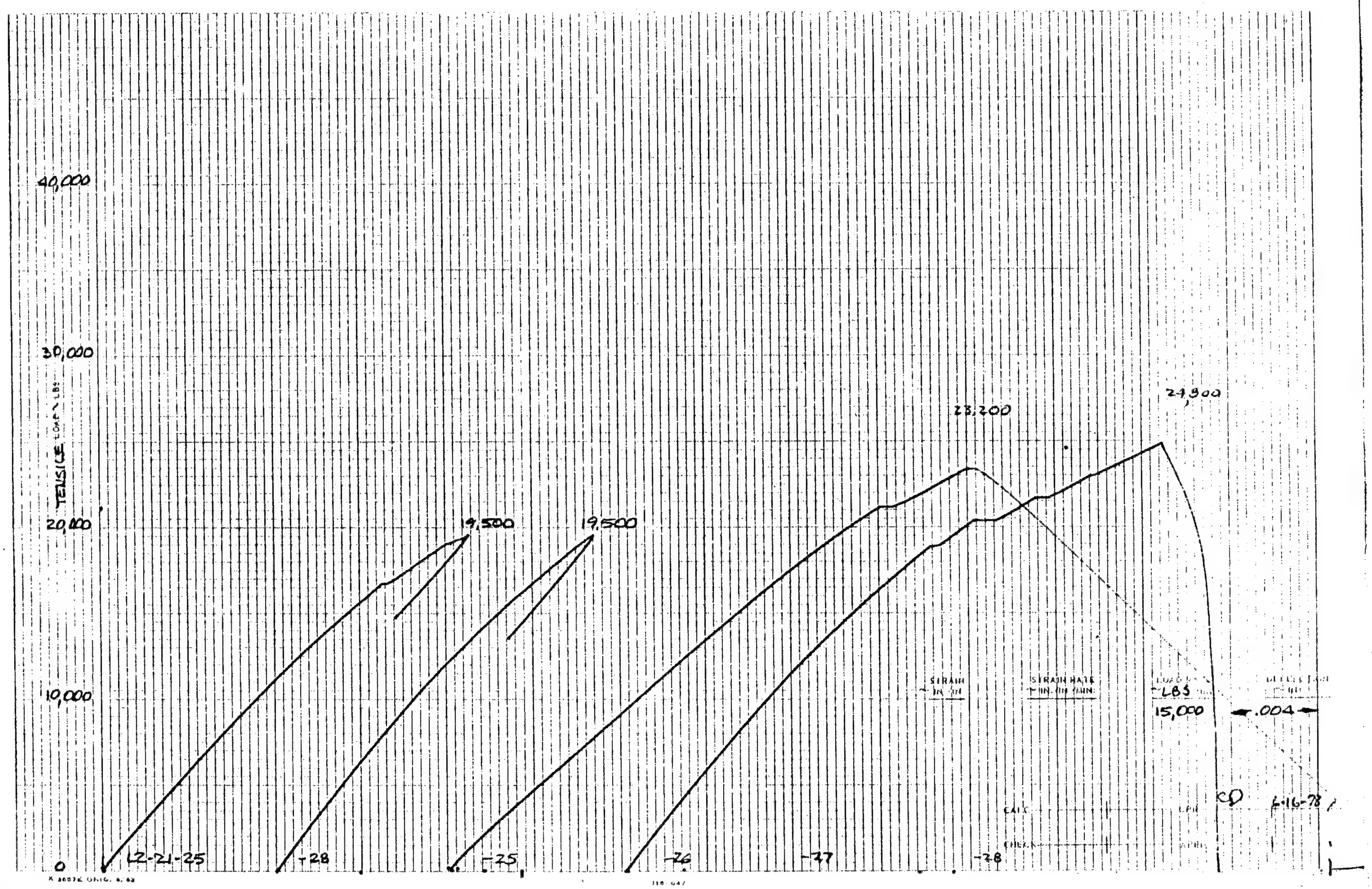
VISUAL DAMAGE

← 0.7–1.0 inch FINE SPLITS →

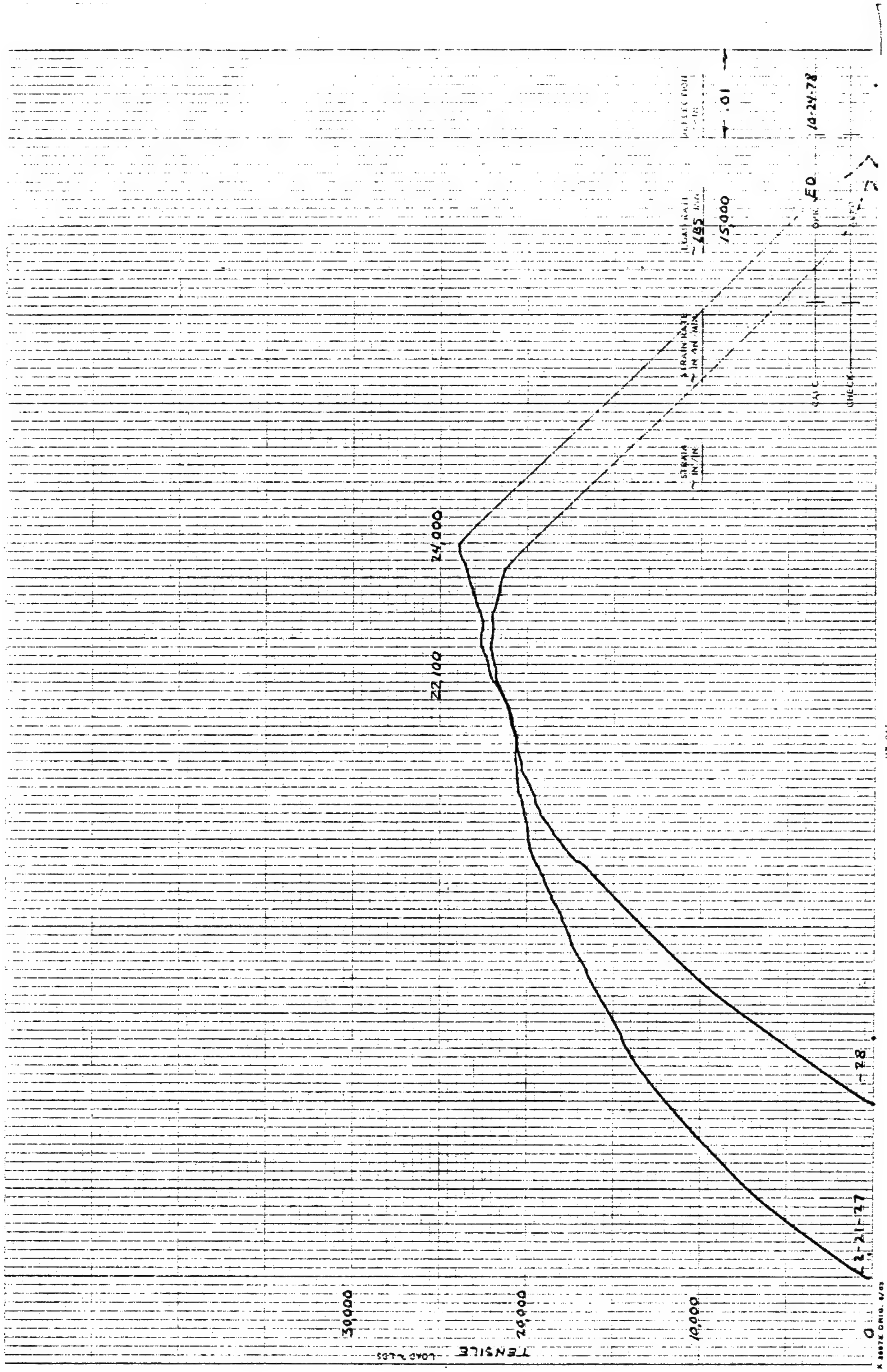


AFTER MOISTURE CONDITIONING





40,000
30,000
20,000
10,000
0
TENSILE LOAD ~ LBS
19,500
19,500
23,200
24,900
L2-21-25
-28
-25
-26
-27
-28
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD ~ LBS
15,000
.004
CALC
CHECK
CD
6-16-78


TENSILE
LOAD ~ LBS
30,000
20,000
10,000
0
24,000
22,100
15,000
.01
10-24-78

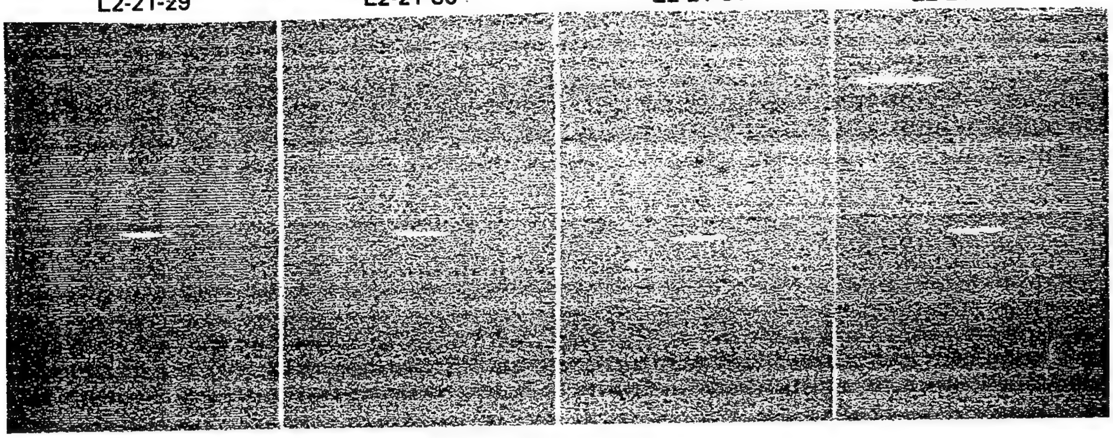
LAMINATE L2
5/8 HP SLIT

TEST SPECIMENS

ROOM TEMPERATURE | 422° K (300° F)

L2-21-29 | L2-21-30 | L2-21-31 | L2-21-32

INITIAL

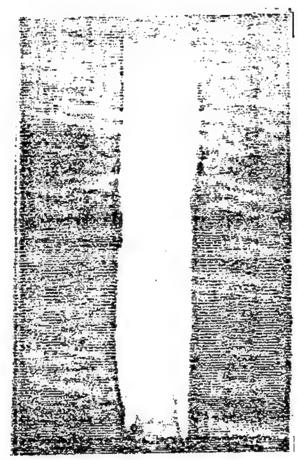


AFTER PRELOAD
28.0 KIP

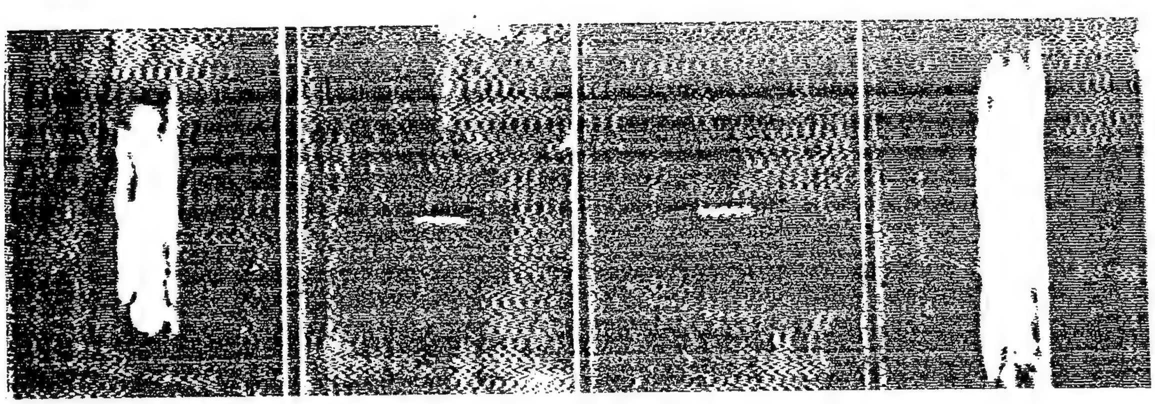
VISUAL DAMAGE

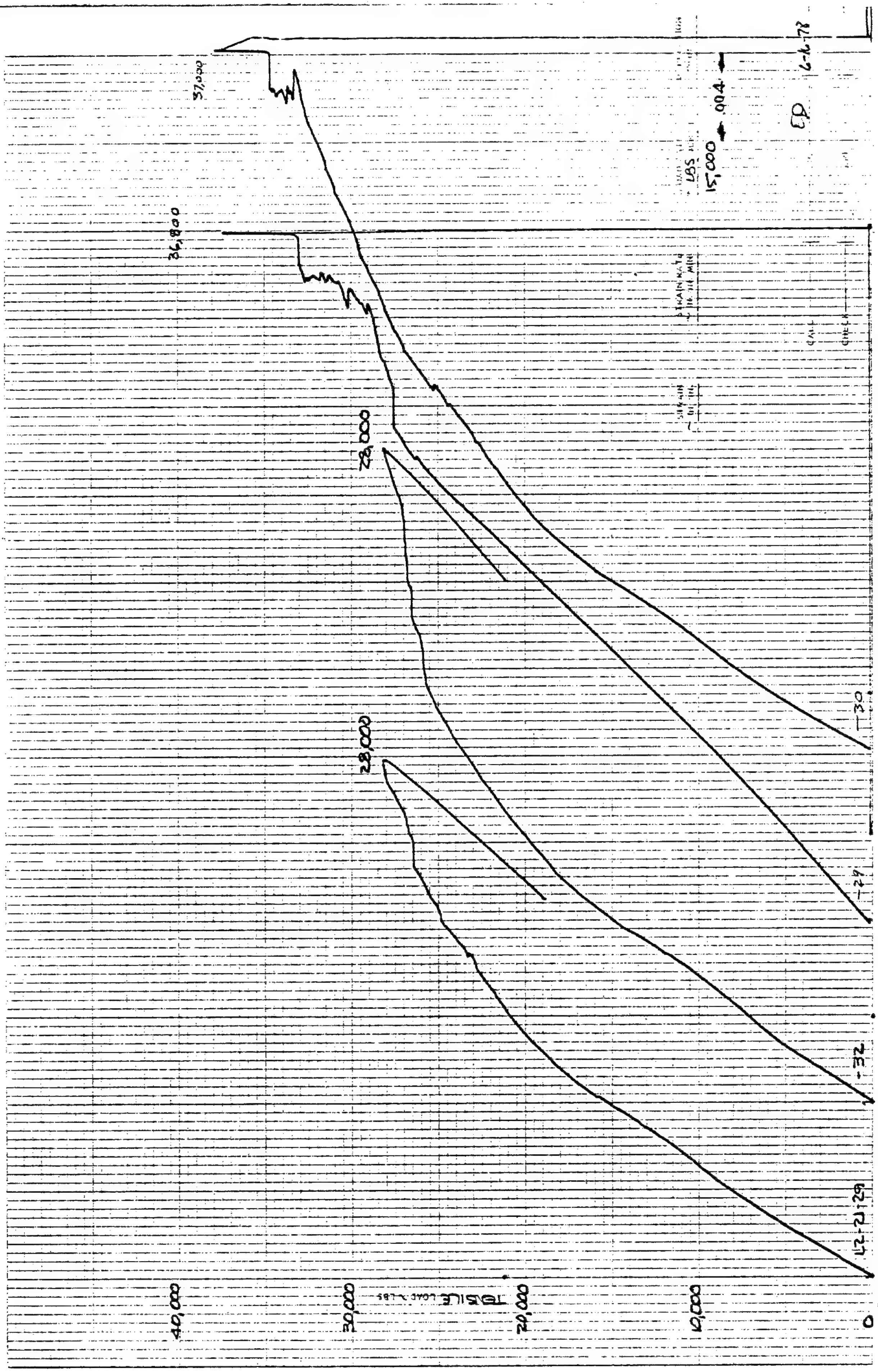
← 1.0–1.4 inch FINE SPLITS

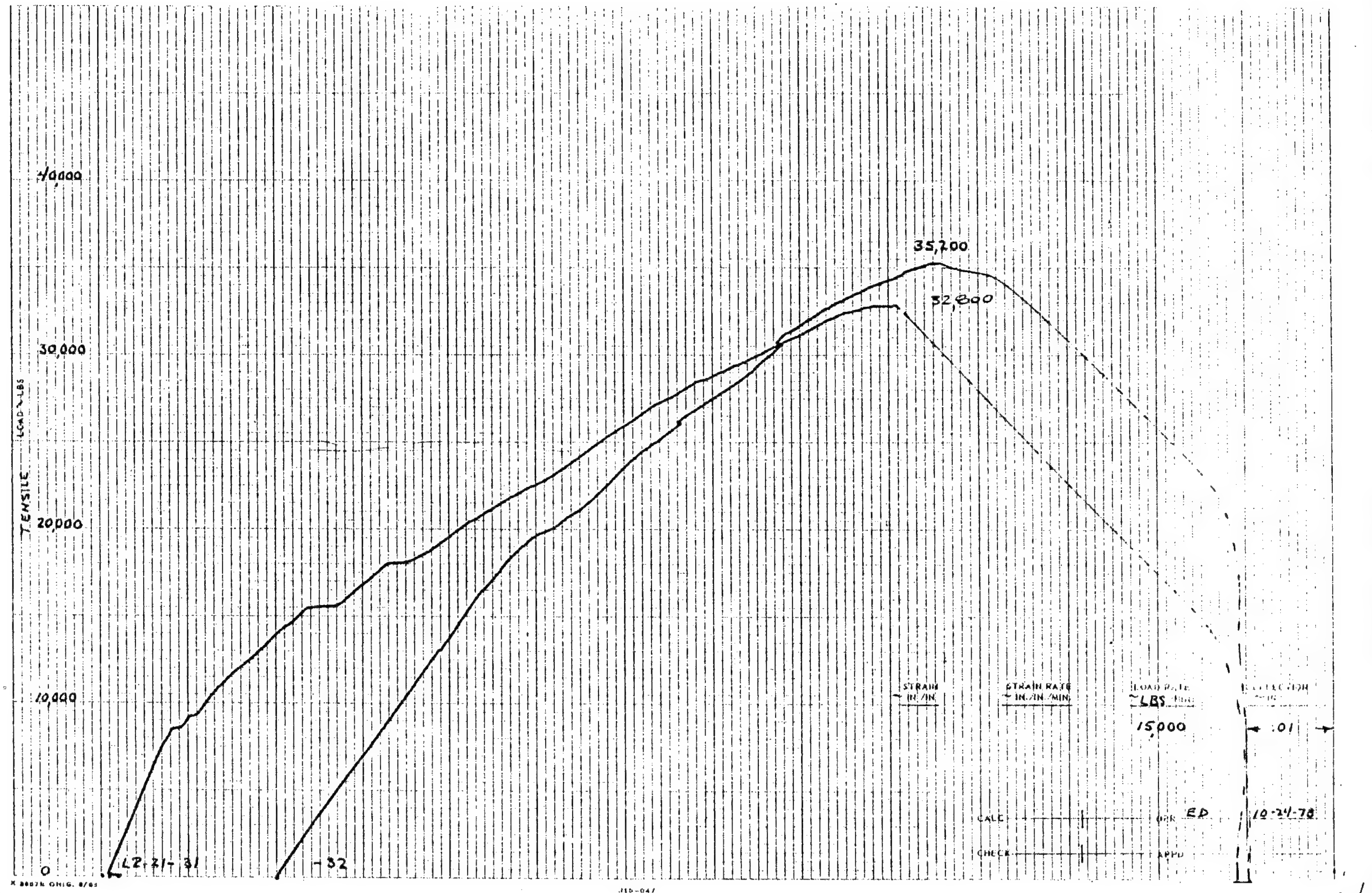
2.1 inch FINE SPLITS →



AFTER MOISTURE CONDITIONING




37,000
36,800
28,000
28,000
40,000
30,000
20,000
10,000
0
TENSILE LOAD - LBS
42-21-29
-30
-29
-32
LBS
15,000
.004
6-6-78


40000
30,000
20000
10,000
0
TENSILE
LOAD ~ LBS
35,200
32,800
L2-21-31
-32
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS
15,000
DEFLECTION
.01
CALC
CHECK
ED
10-24-78
APPD

LAMINATE L2
3/8 FP SLIT

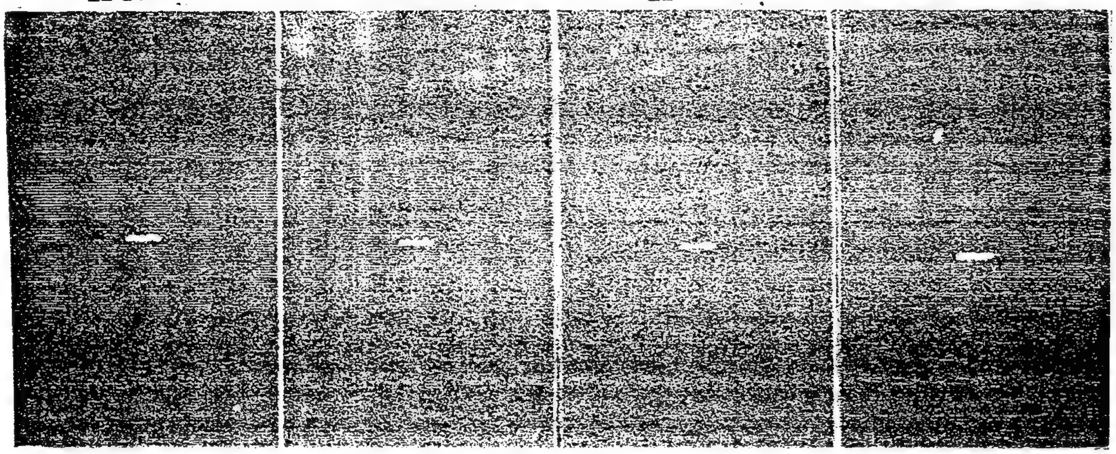
TEST SPECIMENS

ROOM TEMPERATURE

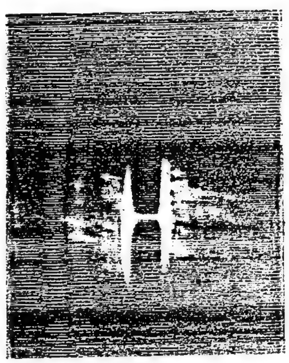
422° K (300° F)

L2-21-41 L2-21-42 L2-21-43 L2-21-44

INITIAL



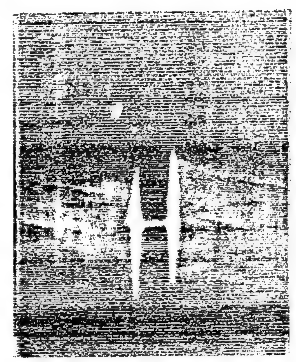
AFTER PRELOAD 23.8 KIP



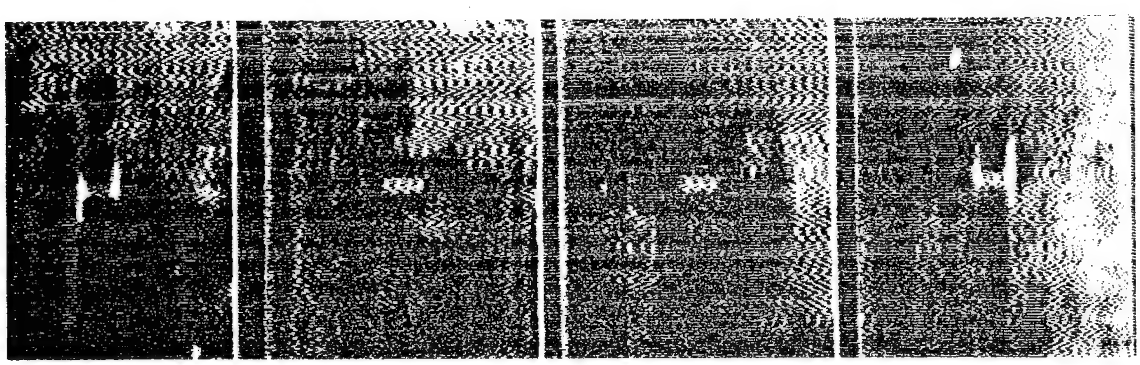
VISUAL DAMAGE

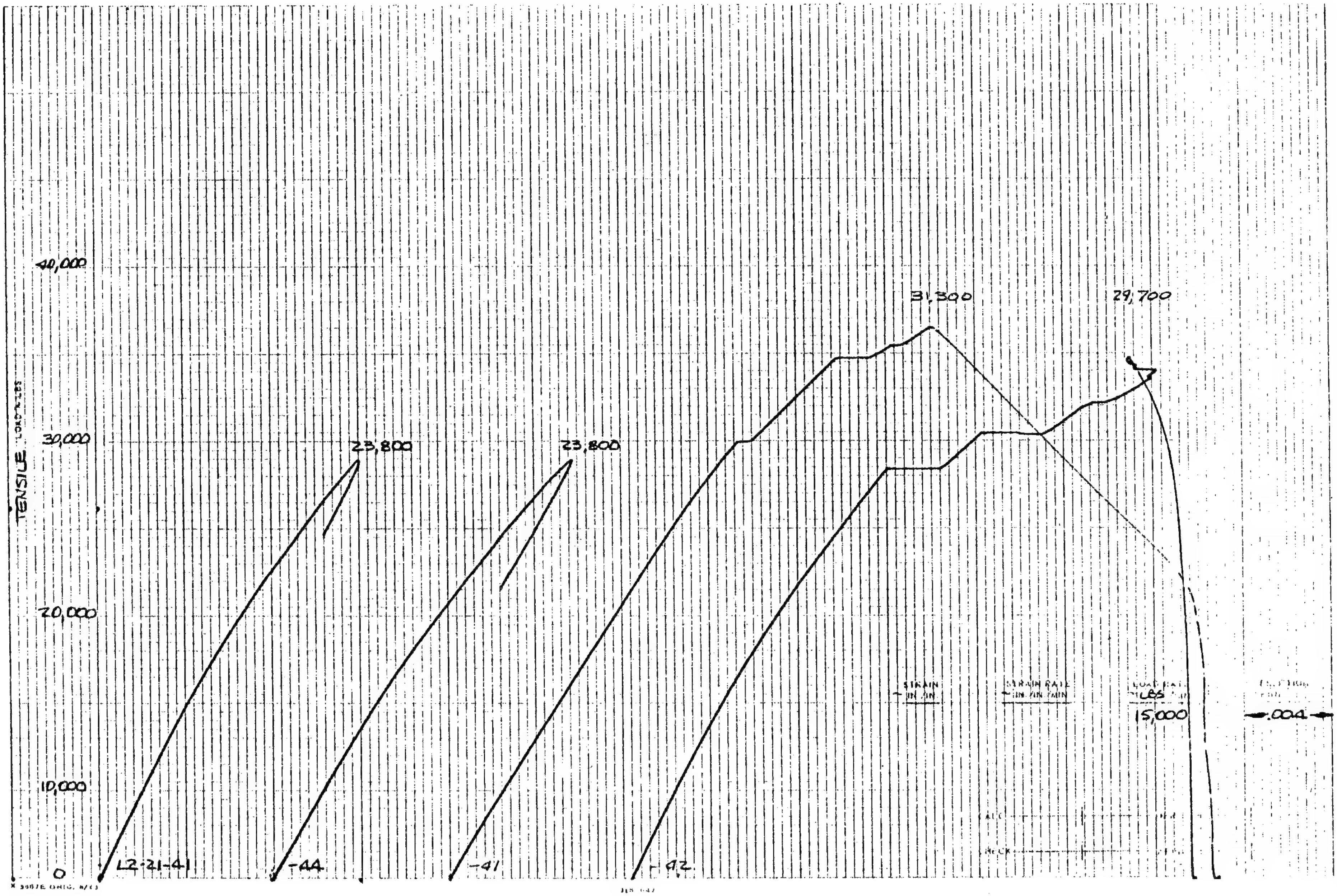
← 0.6–0.8 inch FINE SPLITS

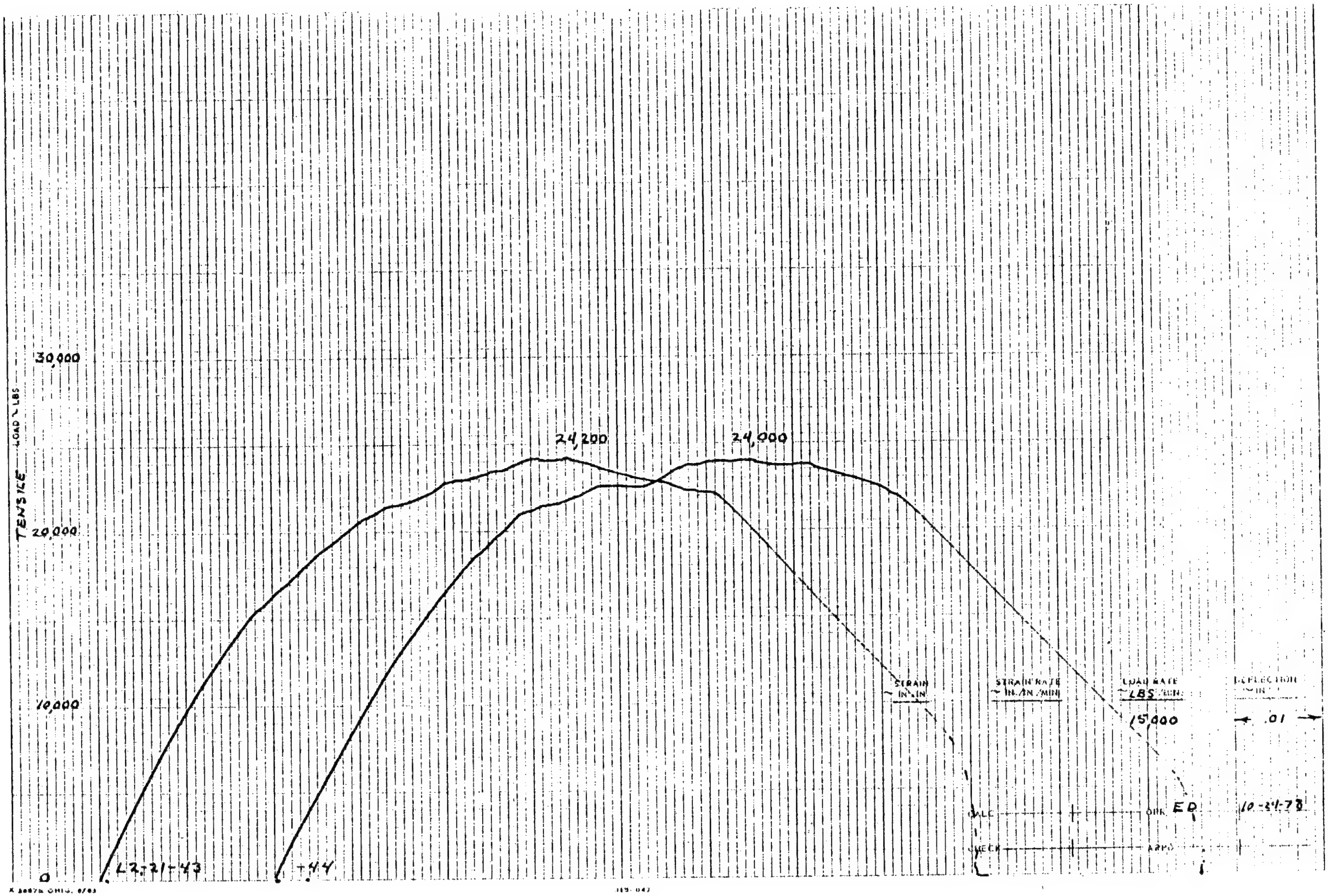
0.8–1.0 inch FINE SPLITS →



AFTER MOISTURE CONDITIONING




TENSILE LOAD LBS
40,000
30,000
20,000
10,000
0
23,800
23,800
31,300
29,700
L2-21-41
-44
-41
-42
STRAIN IN./IN.
STRAIN RATE IN./IN./MIN
LOAD RATE LBS
15,000
.004


TENSILE
LOAD ~ LBS
30,000
20,000
10,000
0
24,200
24,000
L2-21-43
-44
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS/MIN
15,000
DEFLECTION ~ IN
.01
CALC
CHECK
DWN ED
APPD
10-24-78

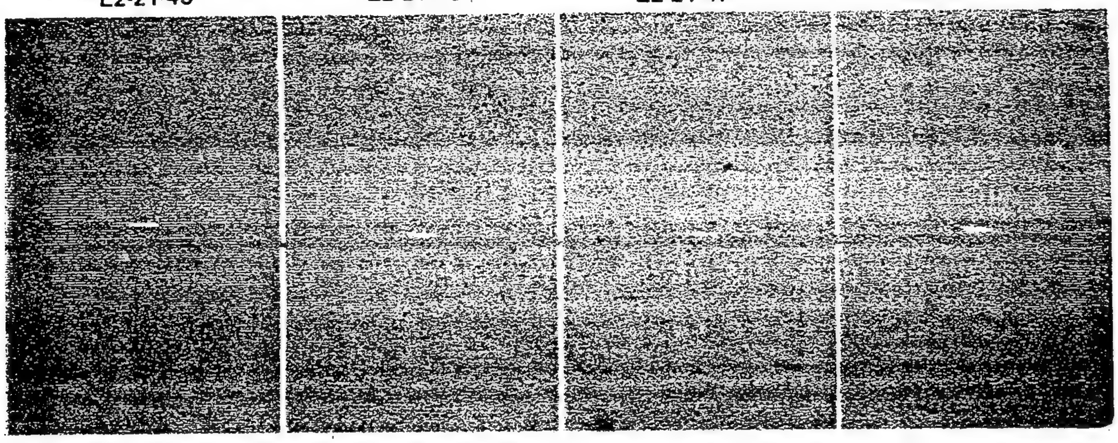
LAMINATE L2
3/8 HP SLIT

TEST SPECIMENS

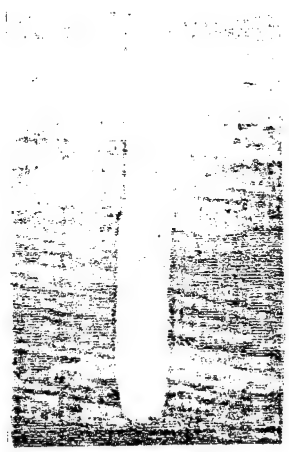
ROOM TEMPERATURE — 422° K (300° F)

L2-21-45 L2-21-46 L2-21-47 L2-21-48

INITIAL

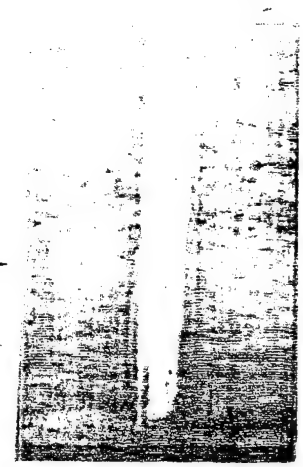


AFTER PRELOAD 32.2 KIP

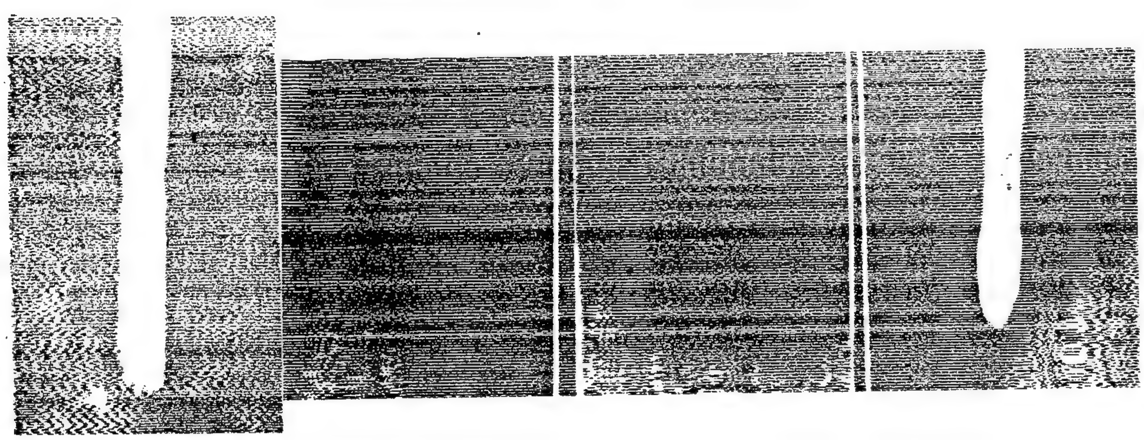


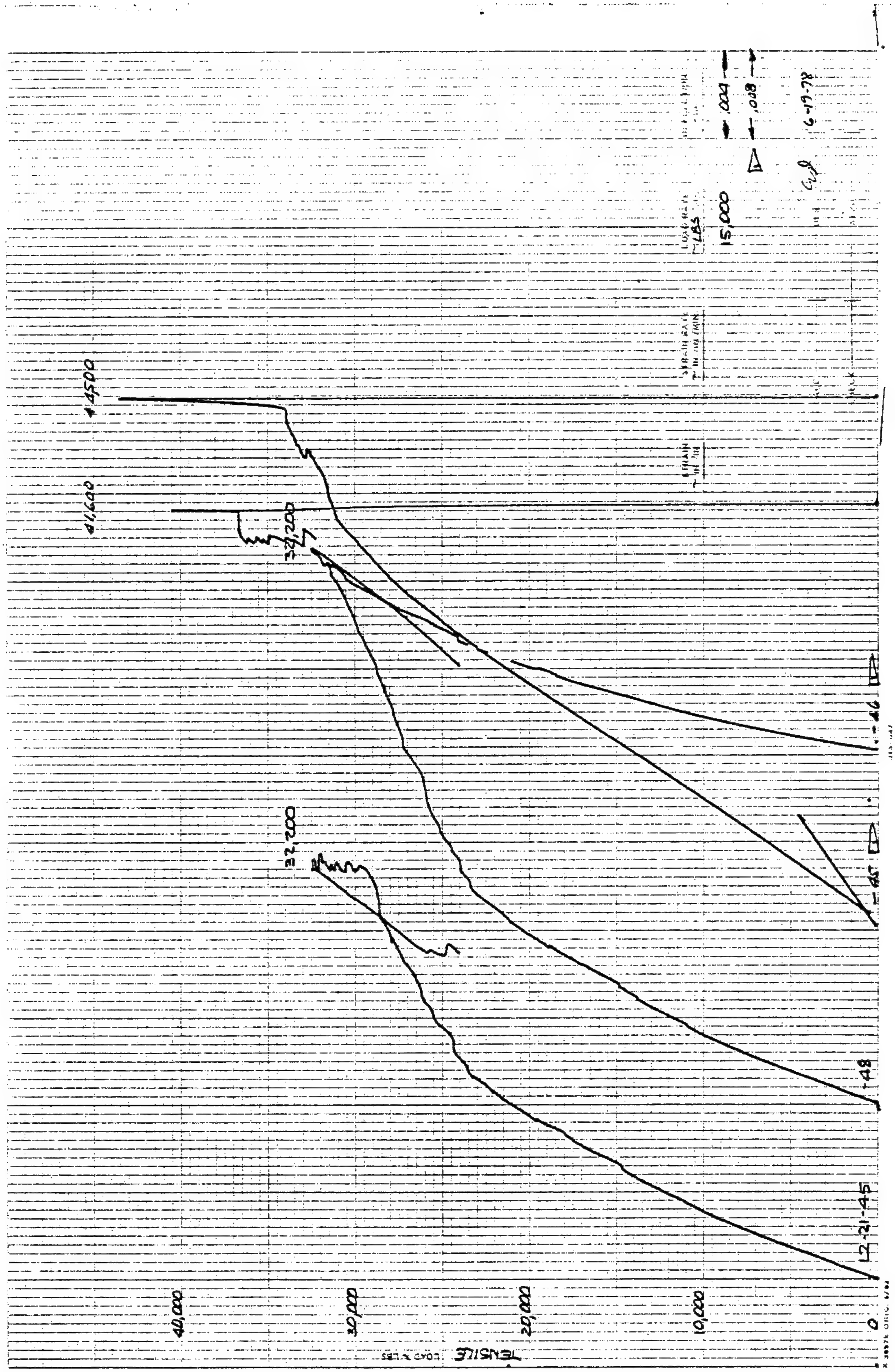
VISUAL DAMAGE

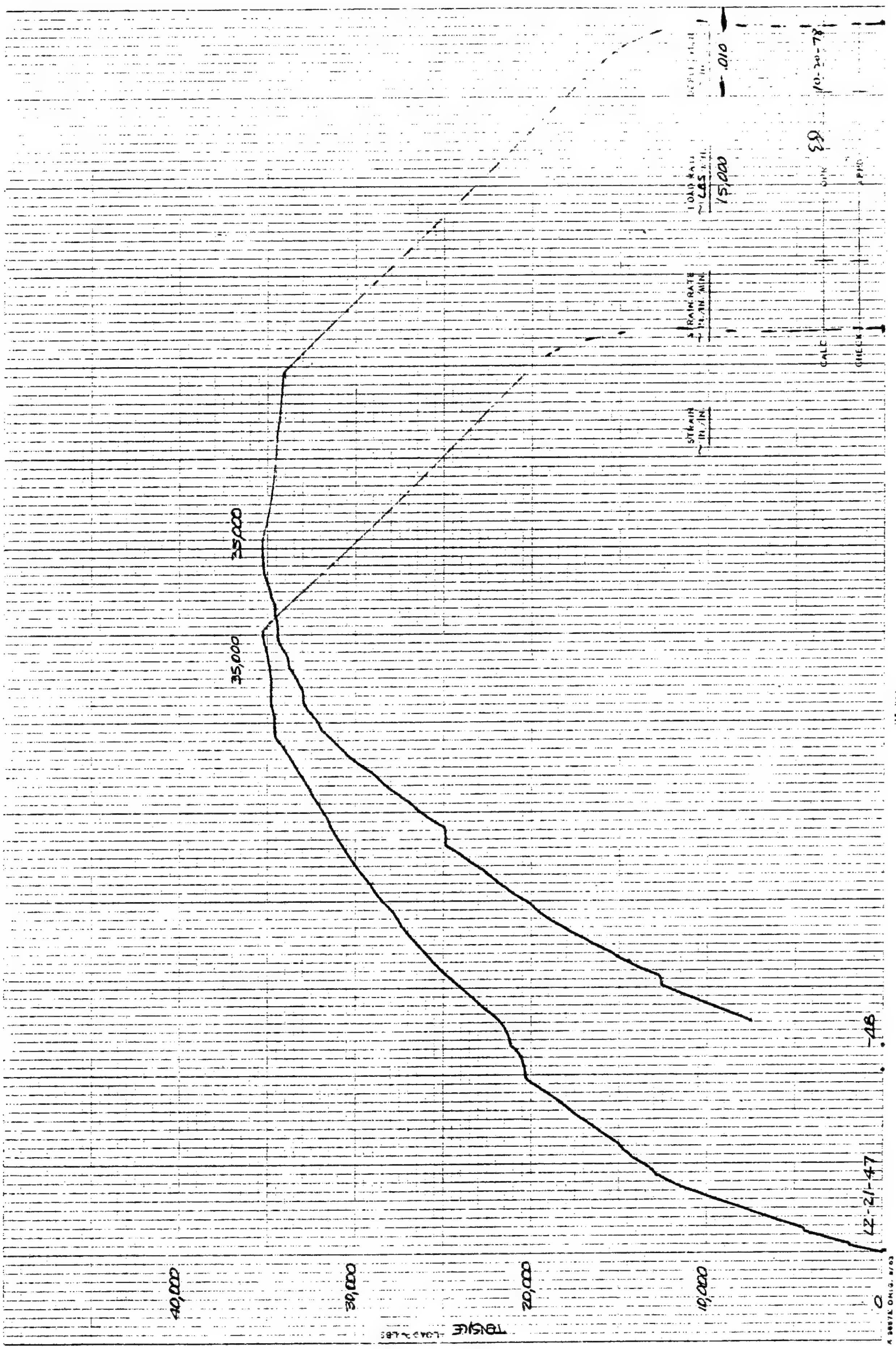
← 2.0–2.5 inch FINE SPLITS →



AFTER MOISTURE CONDITIONING




TENSILE
LOAD LBS
40,000
30,000
20,000
10,000
0
44,500
41,600
32,200
32,200
L2-21-45
48
47
46
15,000
.004
.008
6-19-78


40,000
30,000
20,000
10,000
0
TENSILE
35,000
35,000
42-21-47
.48
15,000
.010
10-20-78

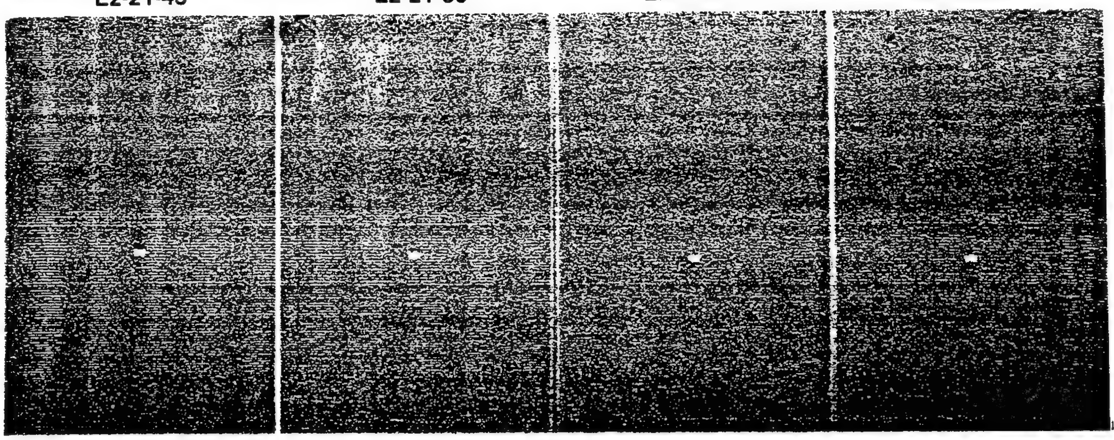
LAMINATE L2
1/8 FP SLIT

TEST SPECIMENS

ROOM TEMPERATURE | 422° K (300° F)

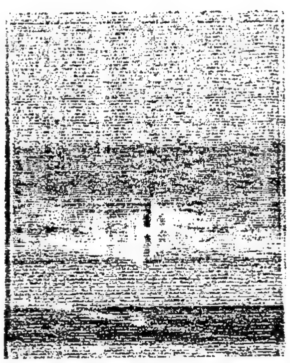
L2-21-49 | L2-21-50 | L2-21-51 | L2-21-52

INITIAL

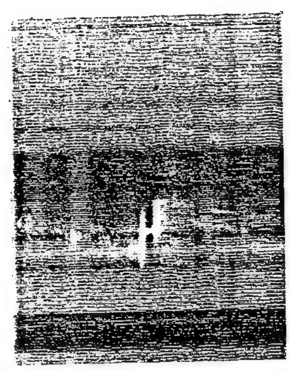


VISUAL DAMAGE

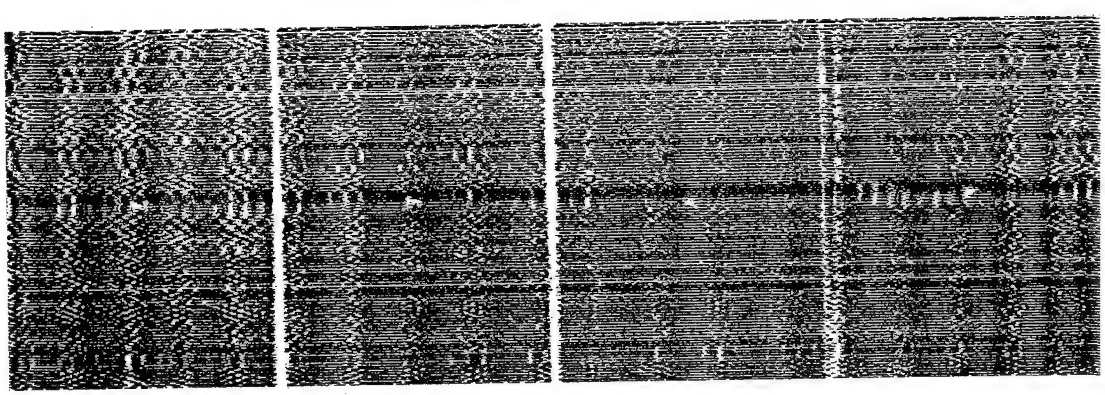
AFTER PRELOAD 24.9 KIP

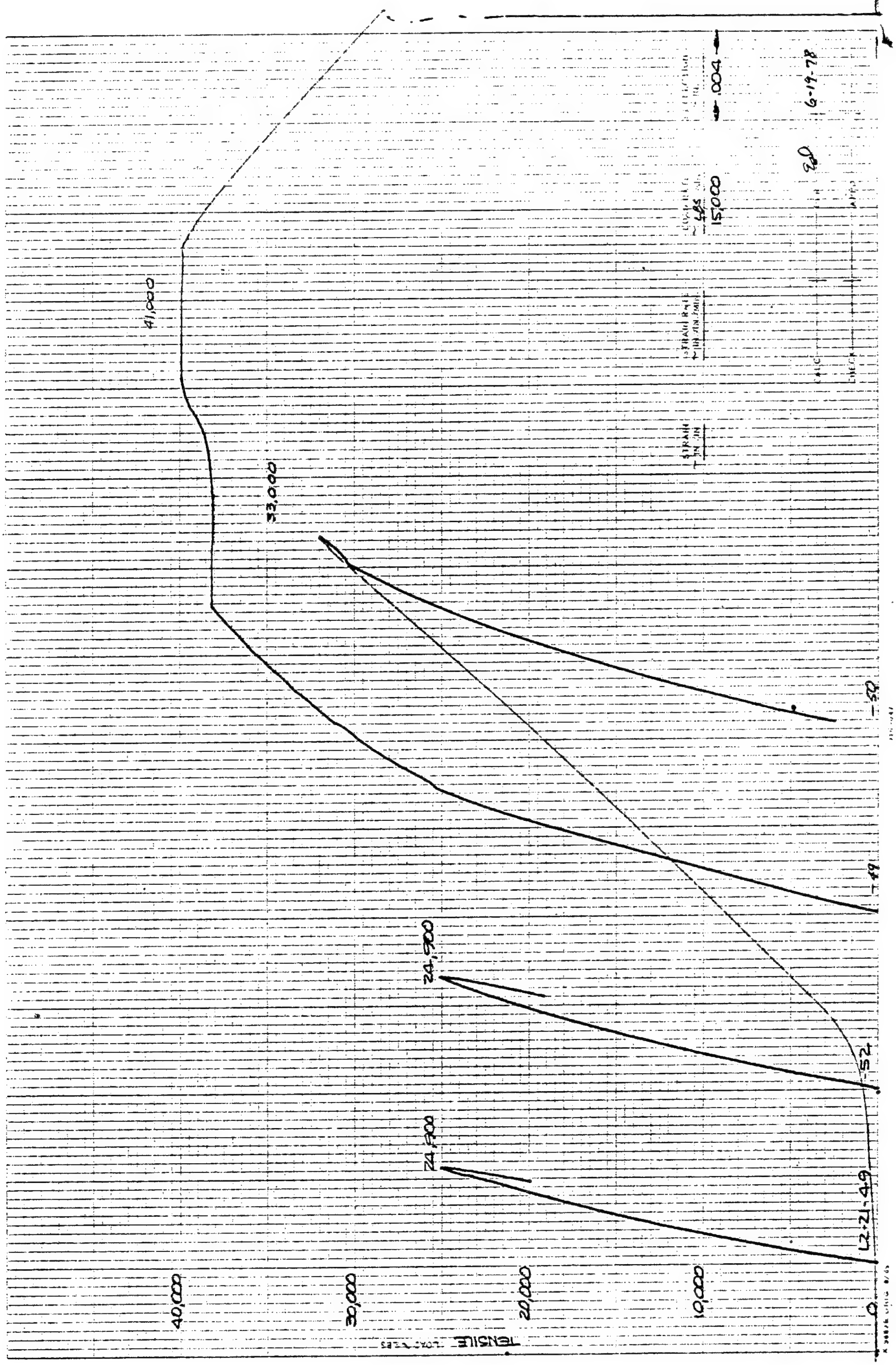


0.3–0.4 inch FINE SPLITS

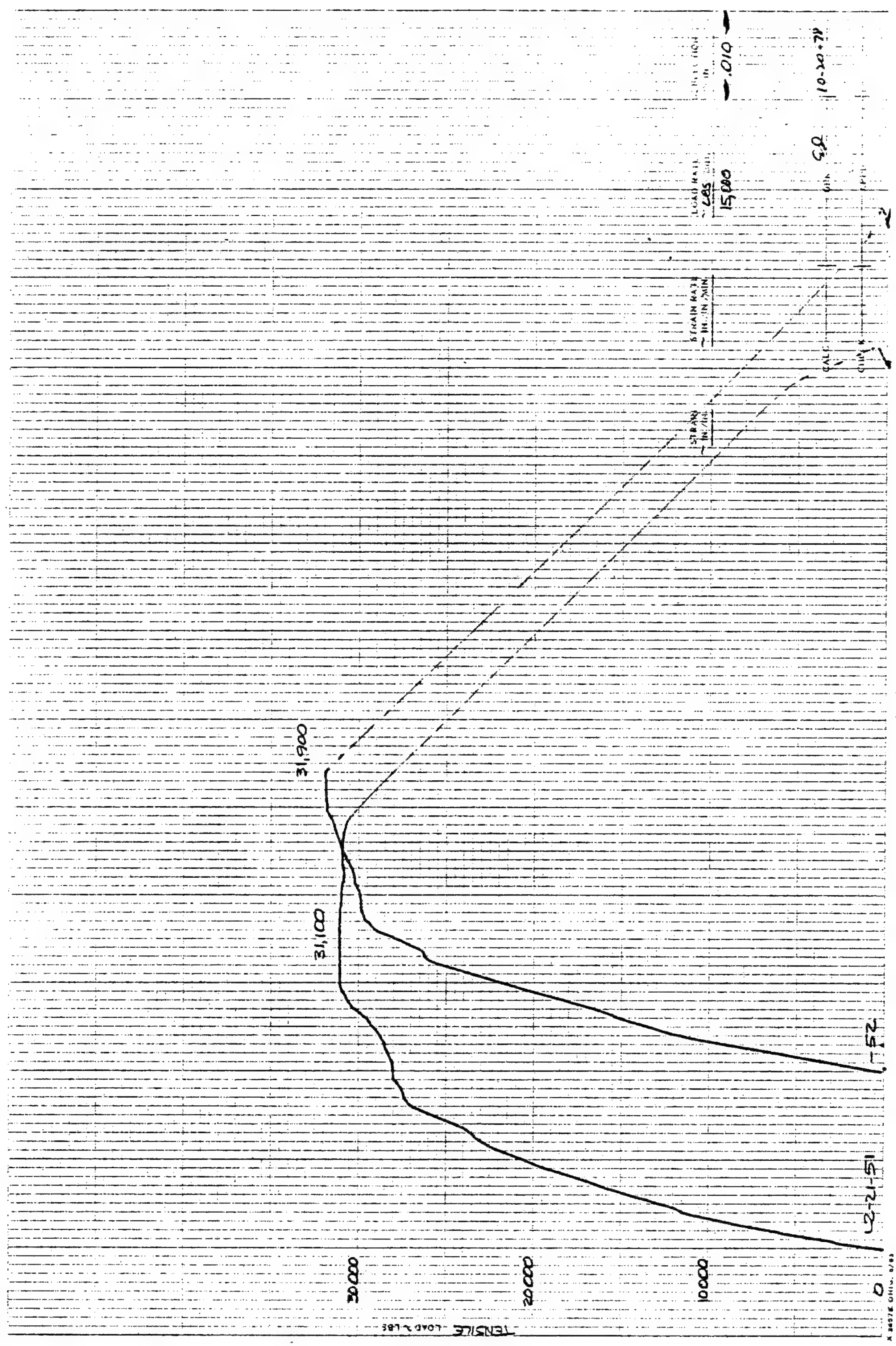


AFTER MOISTURE CONDITIONING





TENSILE
40,000
30,000
20,000
10,000
0
41,000
33,000
24,900
24,900
12-21-49
-52
-49
-50
15,000
.004
6-19-78

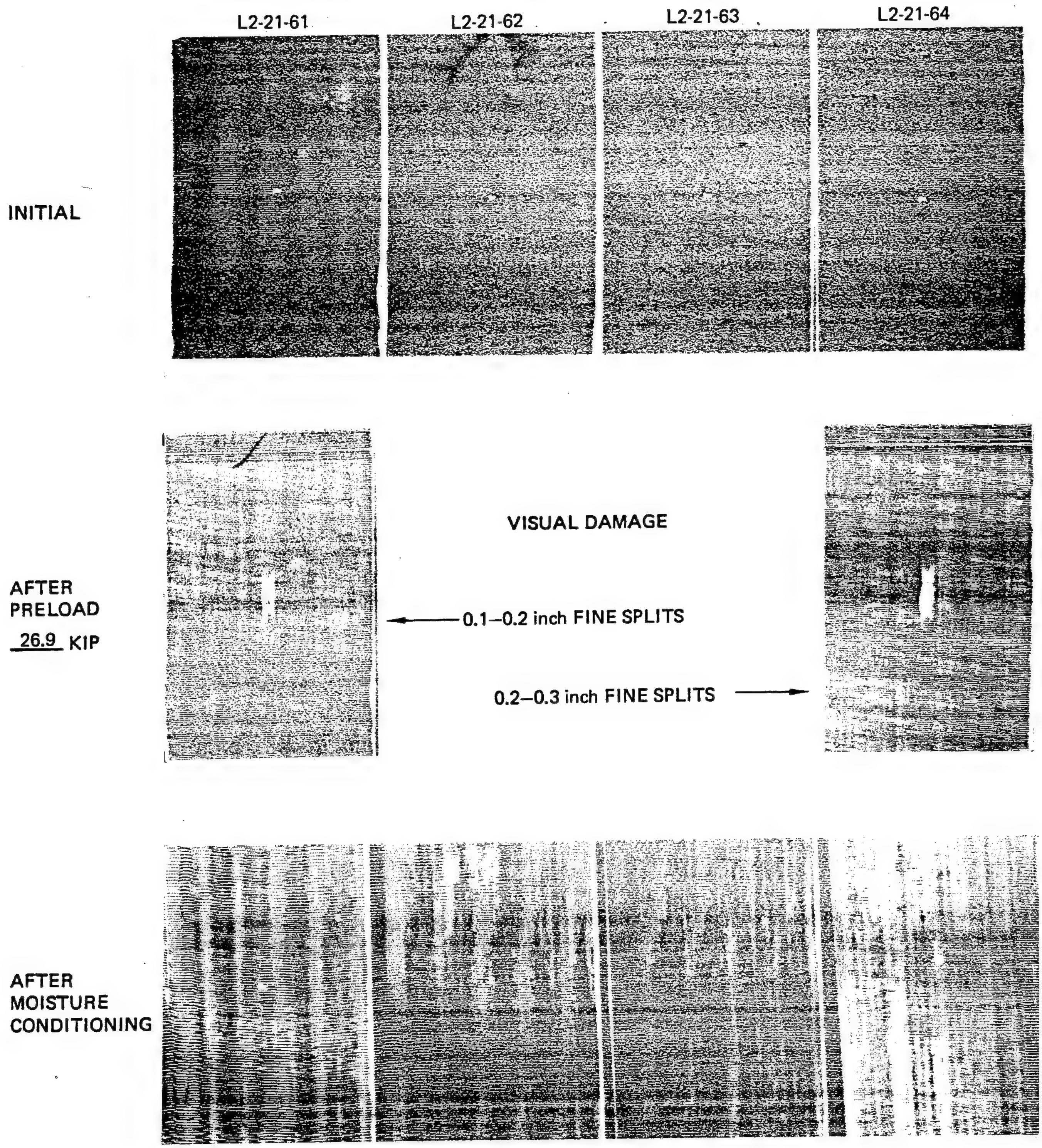


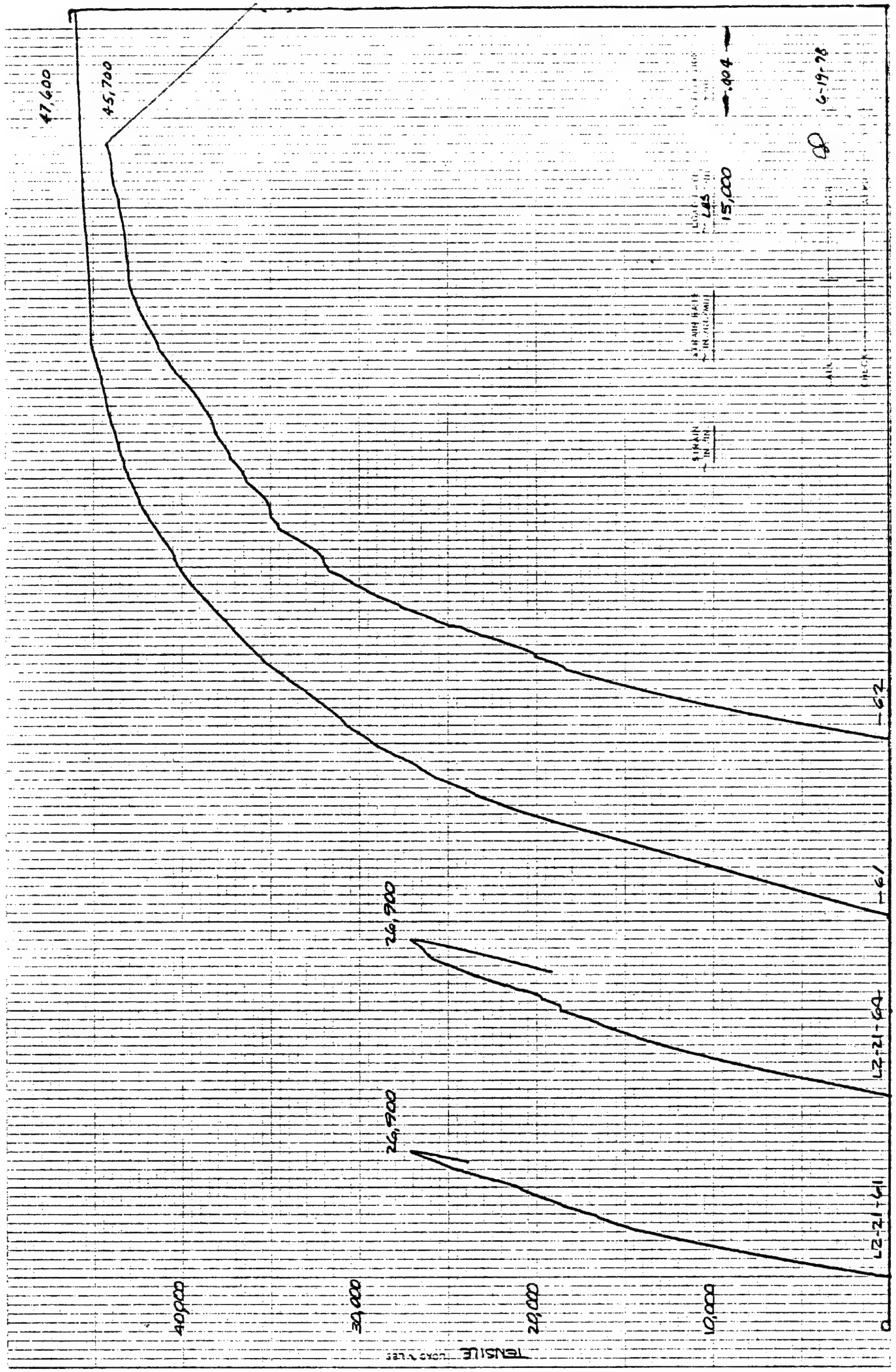
DEFLECTION ~ IN.
.010
10-20-71
LOAD RATE ~ LBS
15,000
STRAIN RATE ~ IN./IN./MIN.
STRAIN ~ IN./IN.
31,900
31,100
1-52
2-21-51
30,000
20,000
10,000
0
TENSILE LOAD ~ LBS

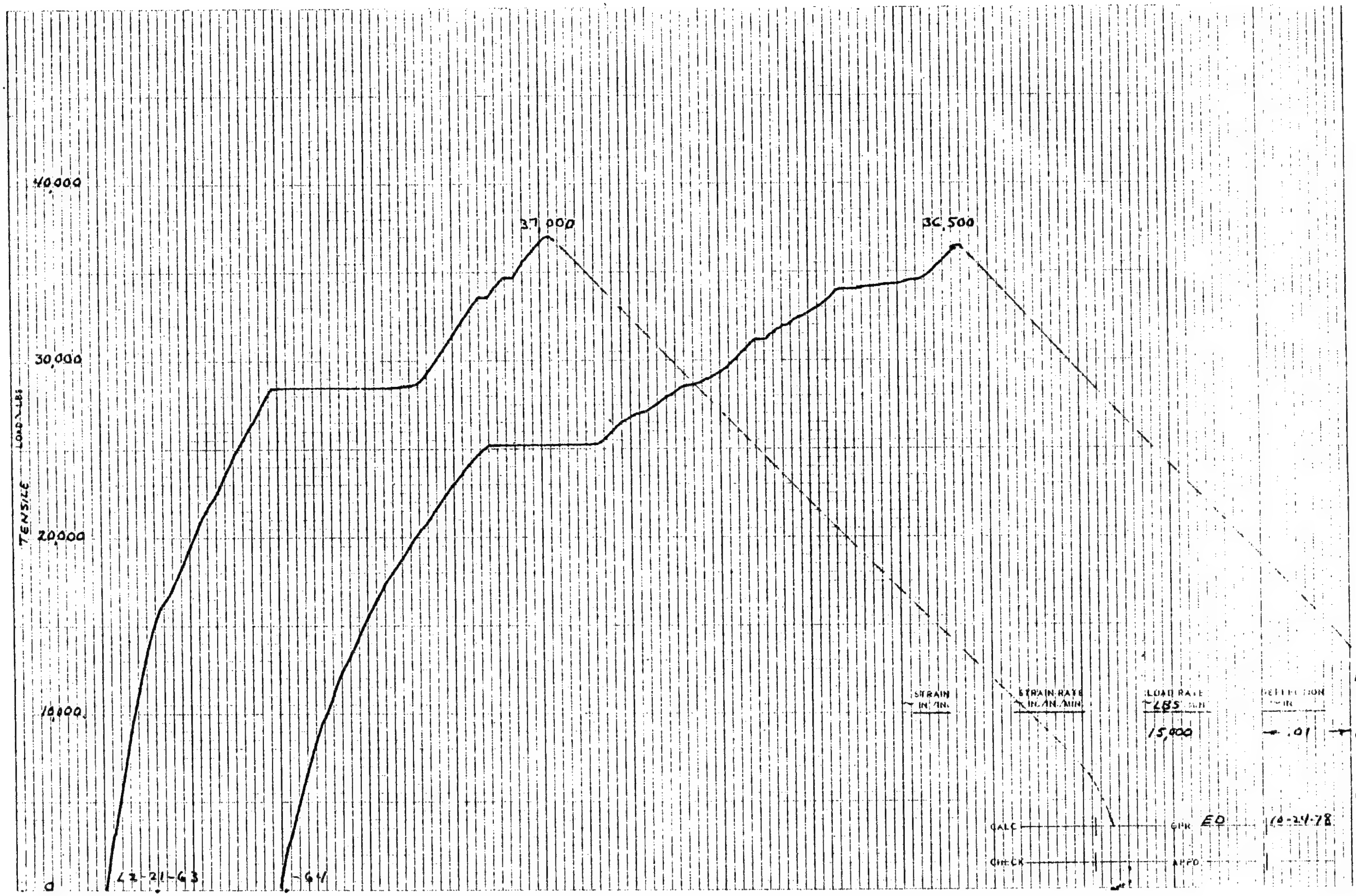
LAMINATE L2
1/8 HP SLIT

TEST SPECIMENS

ROOM TEMPERATURE | 422° K (300° F)




47,600
45,700
26,900
26,900
-62
-61
LZ-21-62
LZ-21-61
40,000
30,000
20,000
10,000
0
TENSILE
LBS
15,000
.004
6-19-78



TENSILE
LOAD ~ LBS
40,000
30,000
20,000
10,000
0
37,000
3C,500
L3-21-63
-64
STRAIN IN/IN
STRAIN RATE IN/IN/MIN
LOAD RATE LBS/MIN
15,000
DEFLECTION IN
.01
CALC
CHECK
CHK ED
APPD
10-24-78

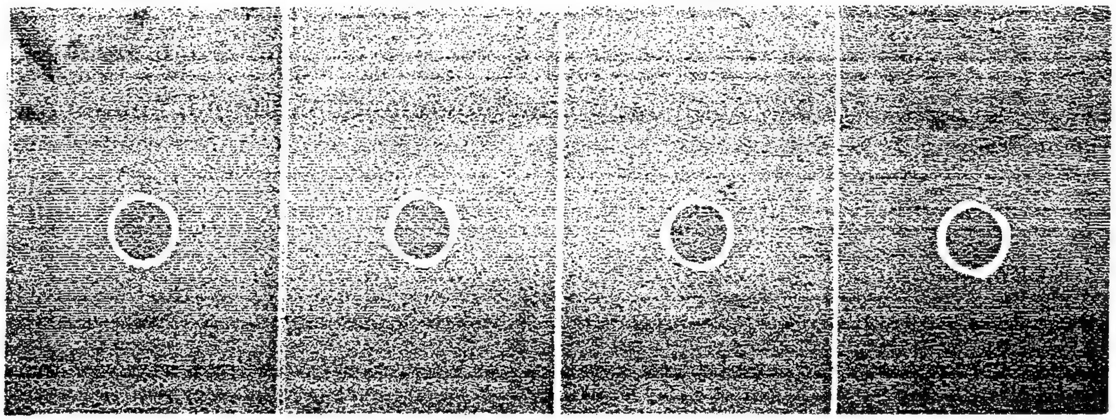
LAMINATE L2
5/8 FP HOLE
50 psi CURE

TEST SPECIMENS

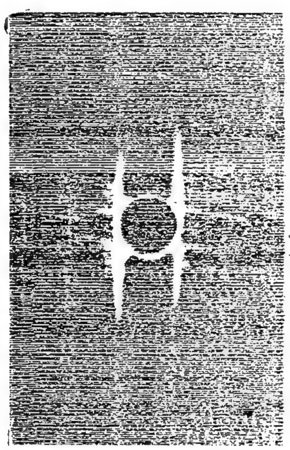
ROOM TEMPERATURE | 422° K (300° F)

L2-22-1 | L2-22-2 | L2-22-3 | L2-22-4

INITIAL



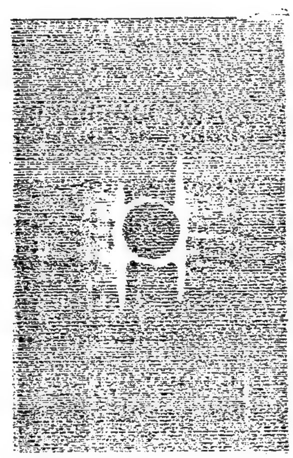
AFTER PRELOAD 17.8 KIP



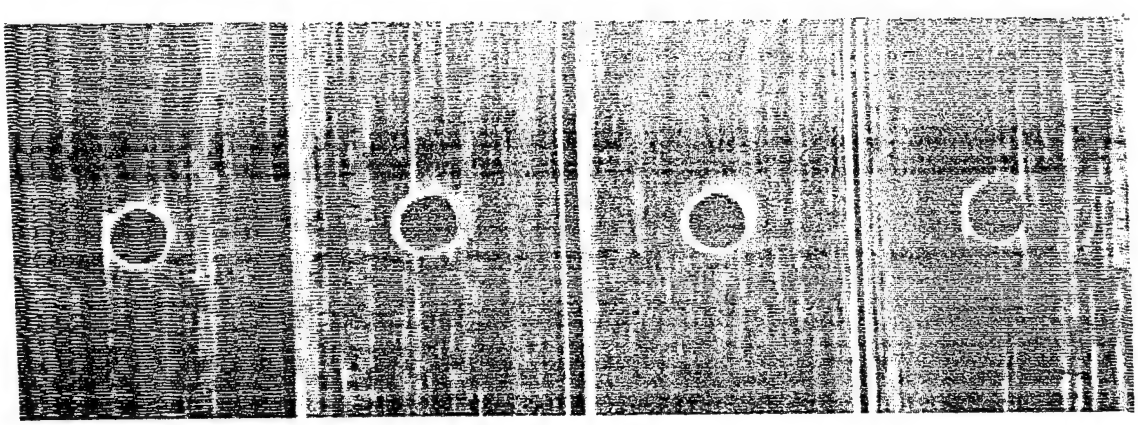
VISUAL DAMAGE

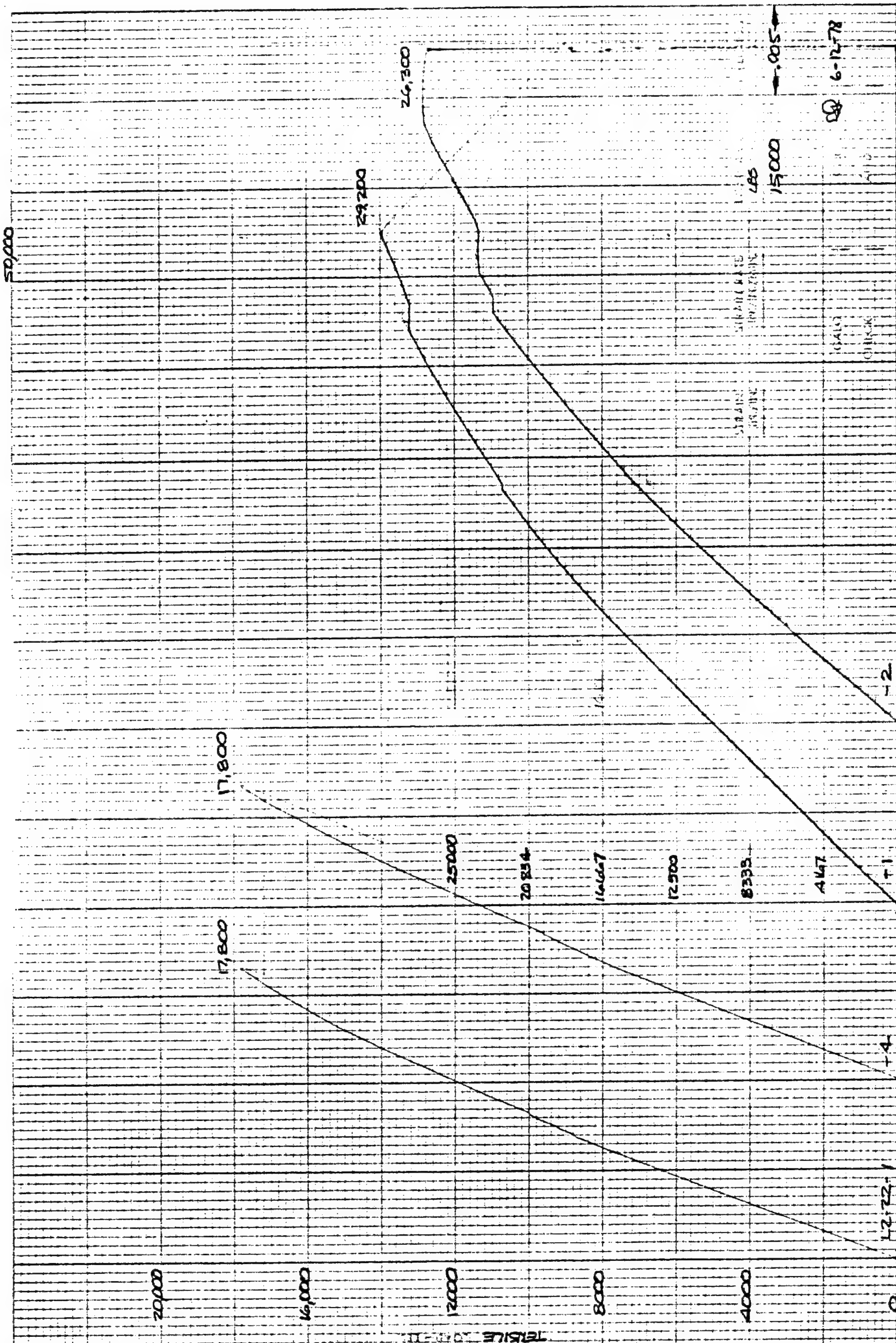
0.8 inch FINE CRACK

0.8–0.9 inch FINE CRACK

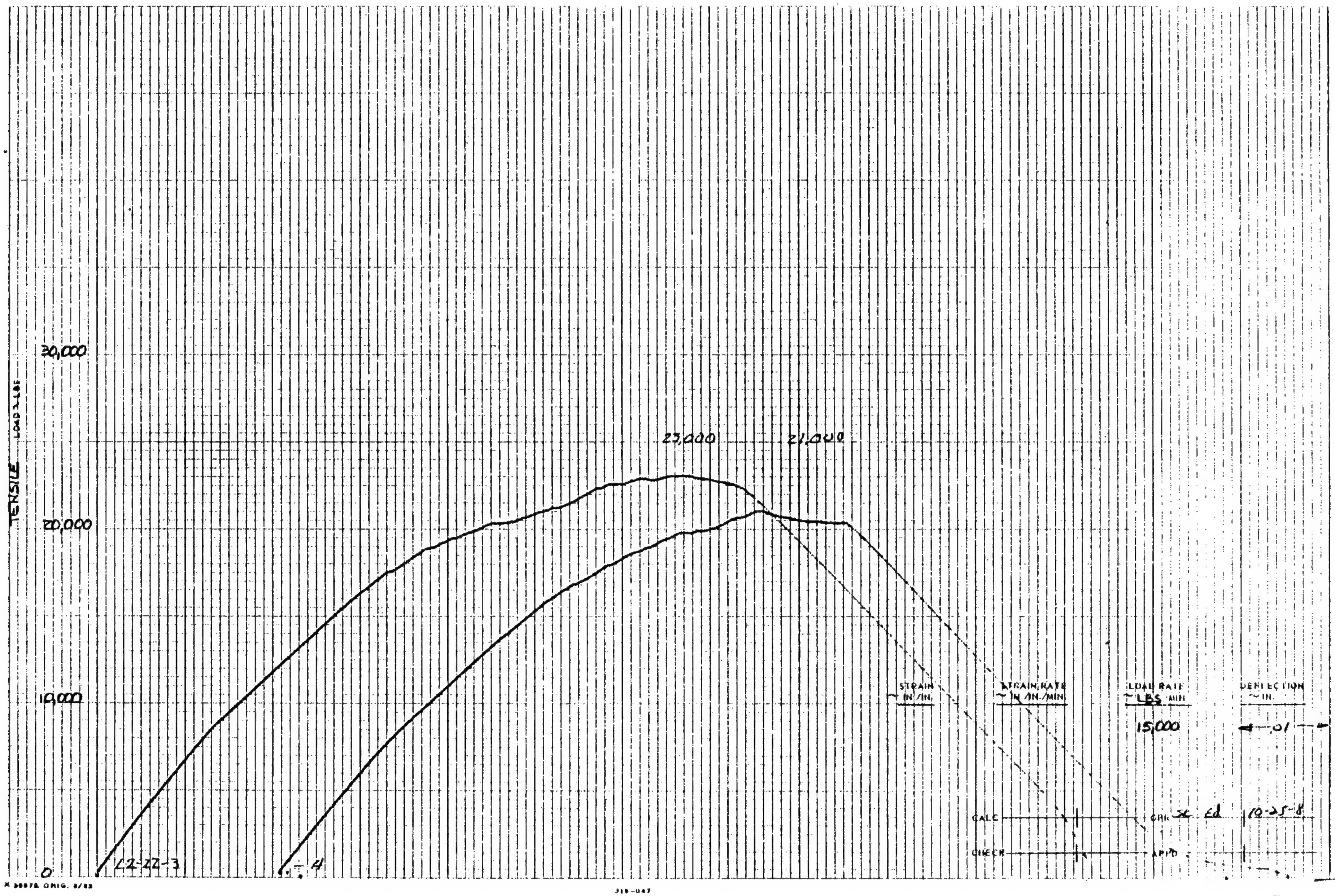


AFTER MOISTURE CONDITIONING





for machine only



TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
23,000
21,000
L2-22-3
4
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN
LOAD RATE ~ LBS/MIN
15,000
DEFLECTION ~ IN.
.01
CALC
CHK
APP'D
CHECK
10-25-8

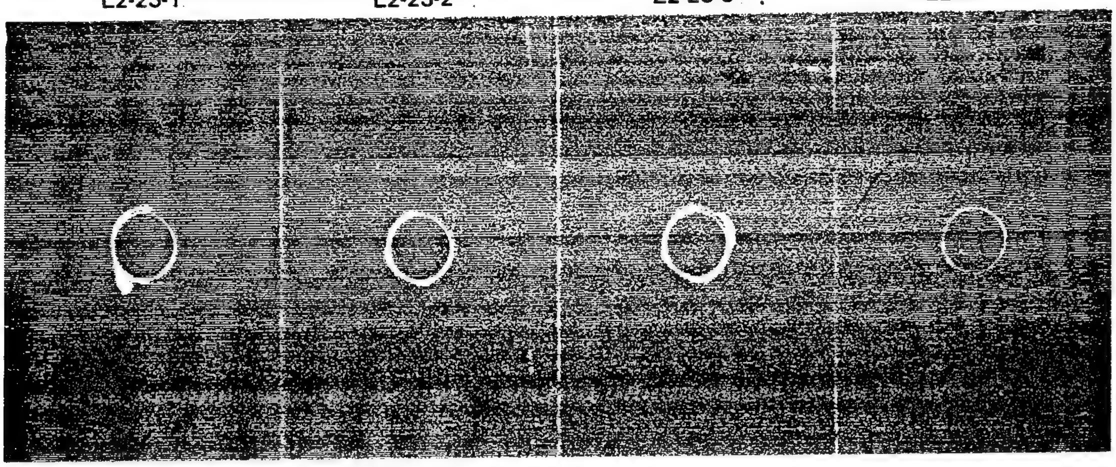
LAMINATE L2
5/8 FP HOLE
25 psi CURE

TEST SPECIMENS

ROOM TEMPERATURE | 422° K (300° F)

L2-23-1 | L2-23-2 | L2-23-3 | L2-23-4

INITIAL

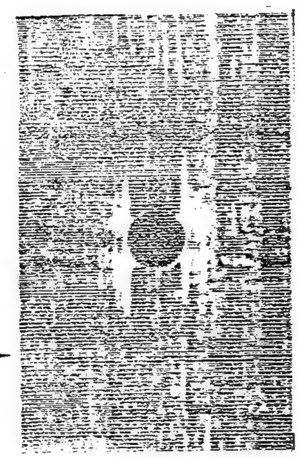


AFTER PRELOAD 18.2 KIP

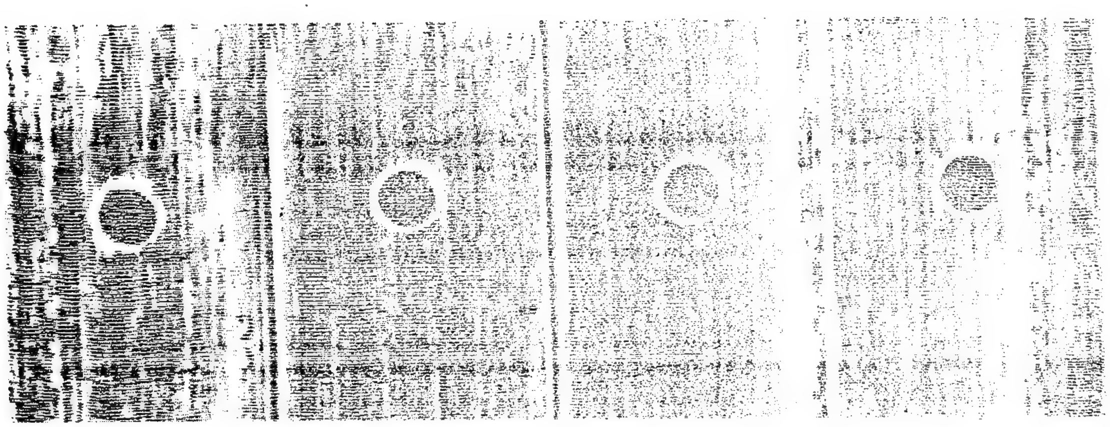
VISUAL DAMAGE

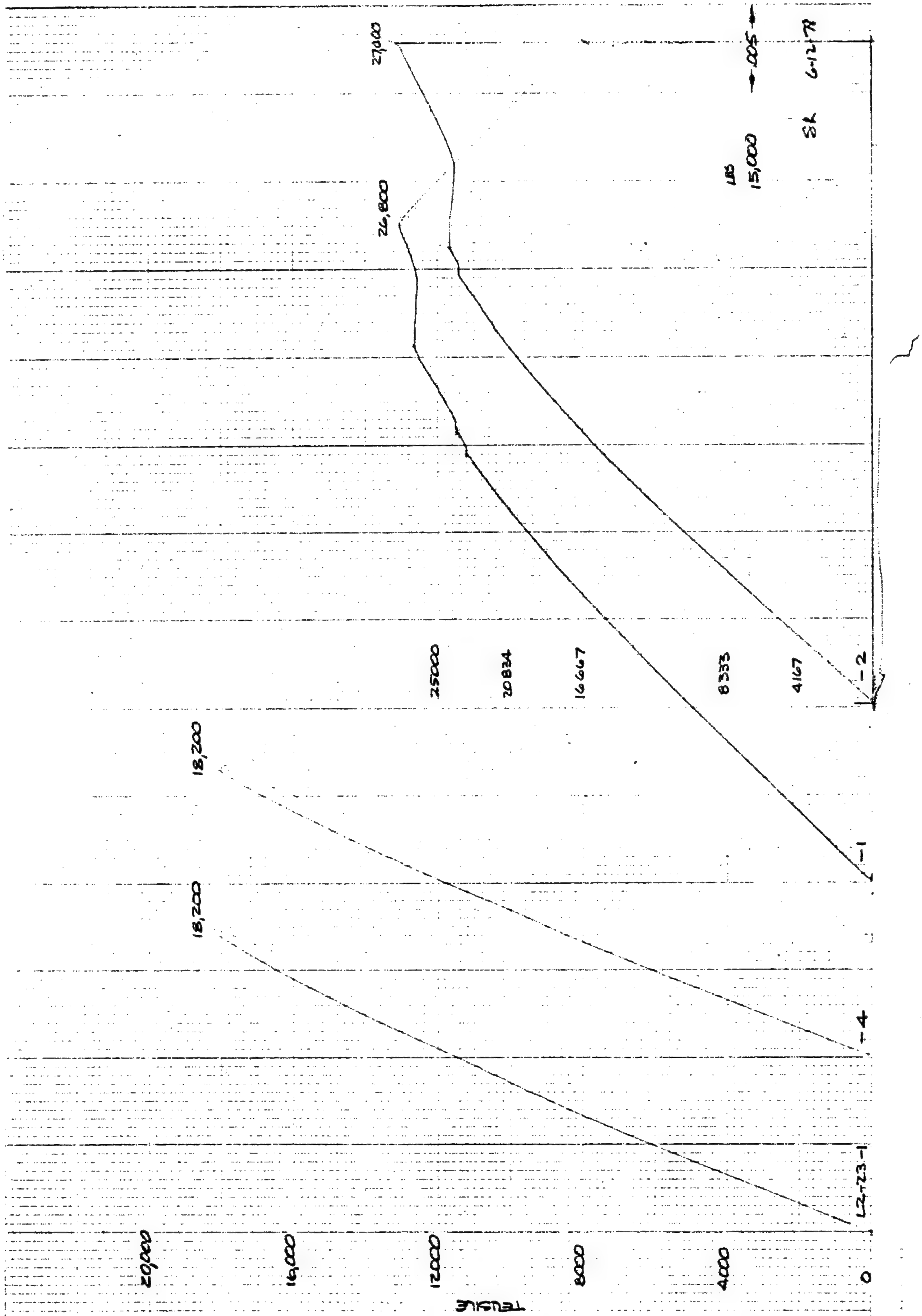
0.8–0.9 inch FINE CRACKS

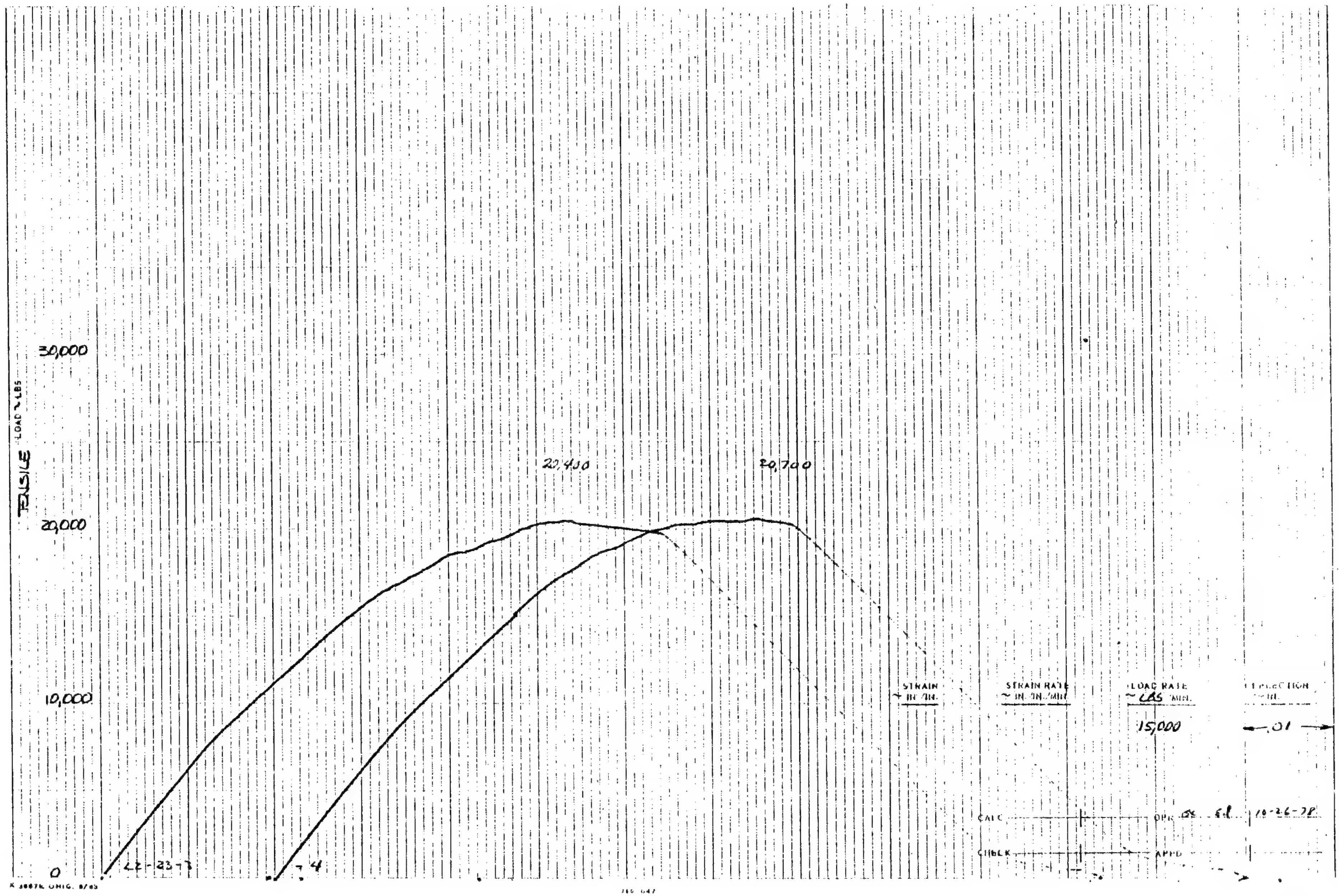
~ 0.8 inch FINE CRACKS



AFTER MOISTURE CONDITIONING




TENSILE
0
4000
8000
12000
16,000
20,000
L2-T23-1
-4
-1
-2
18,200
18,200
4167
8333
16667
20834
25000
26,800
27,000
LBS
15,000
.005
SL
6-12-78


TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
22-23-3
-4
20,400
20,700
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE ~ LBS/MIN.
15,000
.01
CALC
CHECK
APPD
10-26-78

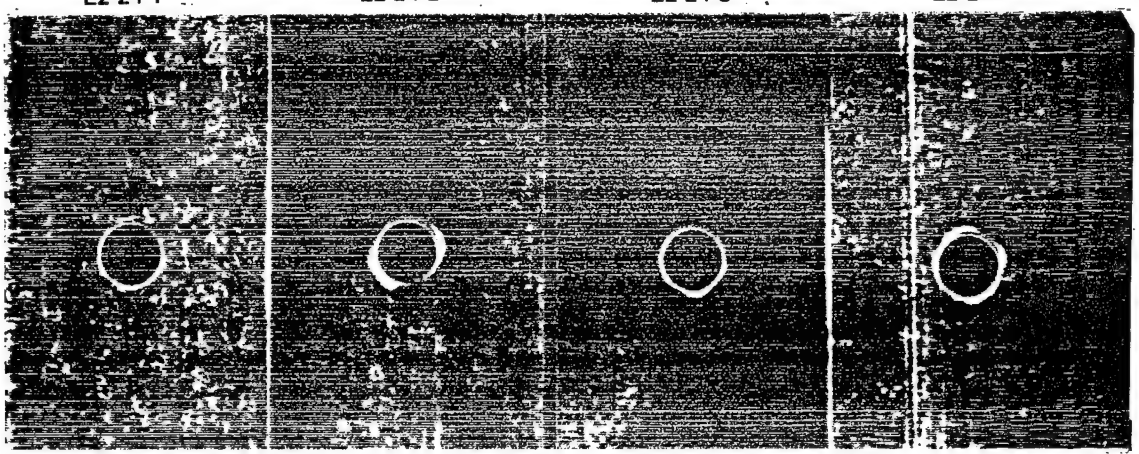
LAMINATE L2
5/8 FP HOLE
12.5 psi CURE

TEST SPECIMENS

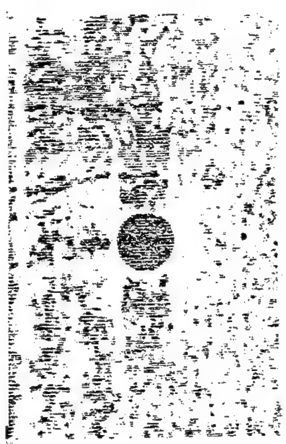
ROOM TEMPERATURE | 422° K (300° F)

L2-24-1 | L2-24-2 | L2-24-3 | L2-24-4

INITIAL



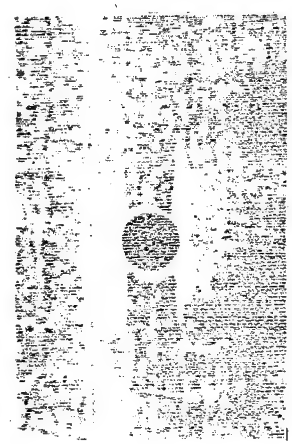
AFTER PRELOAD
20.2 KIP



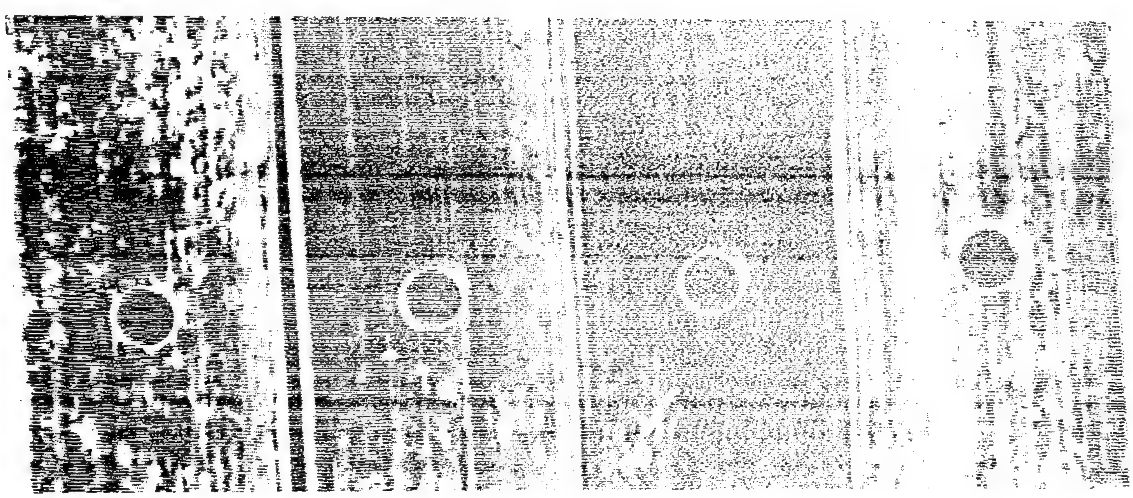
VISUAL DAMAGE

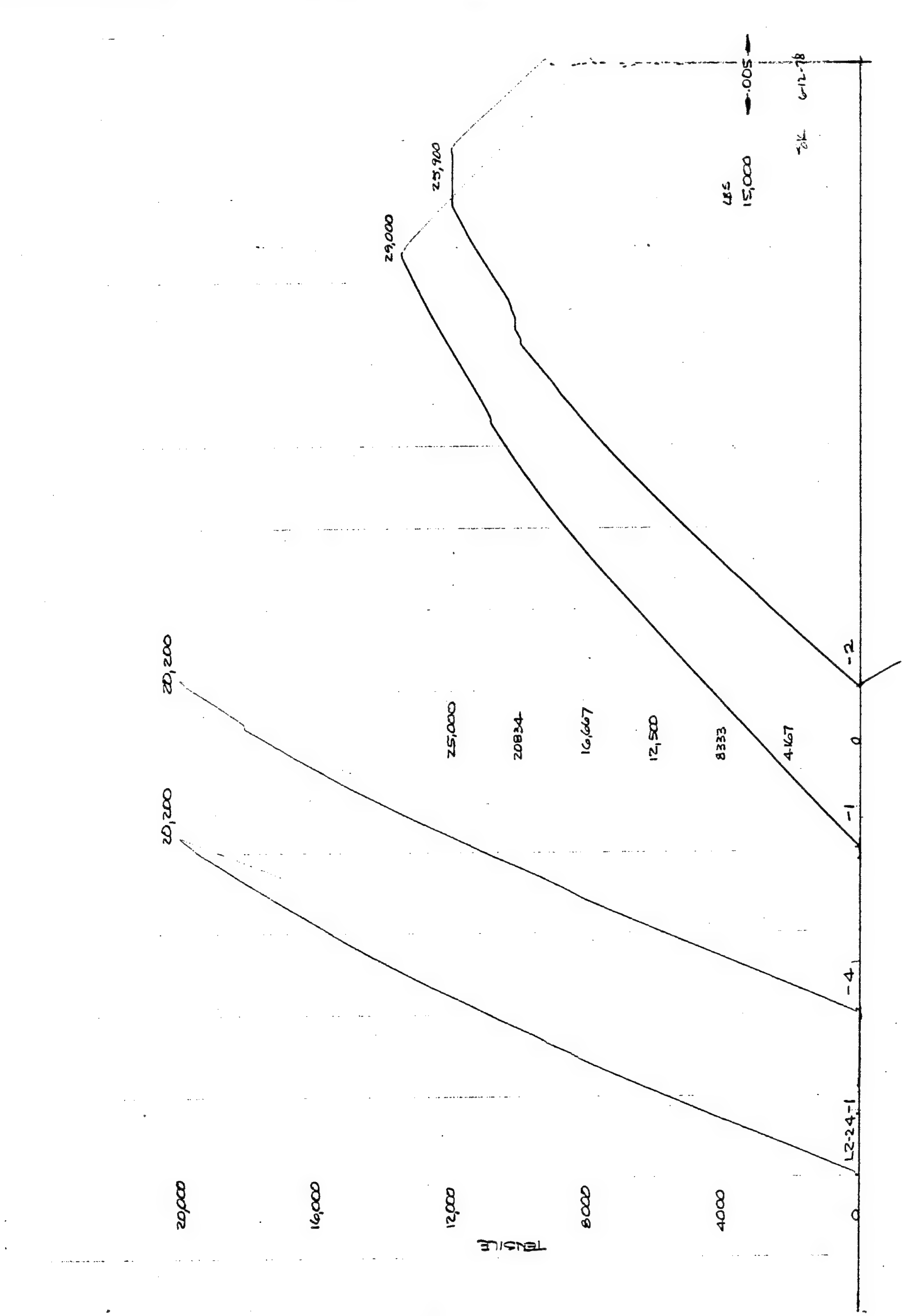
← 1.0–1.2 inch FINE CRACKS →

NO EDGE DAMAGE

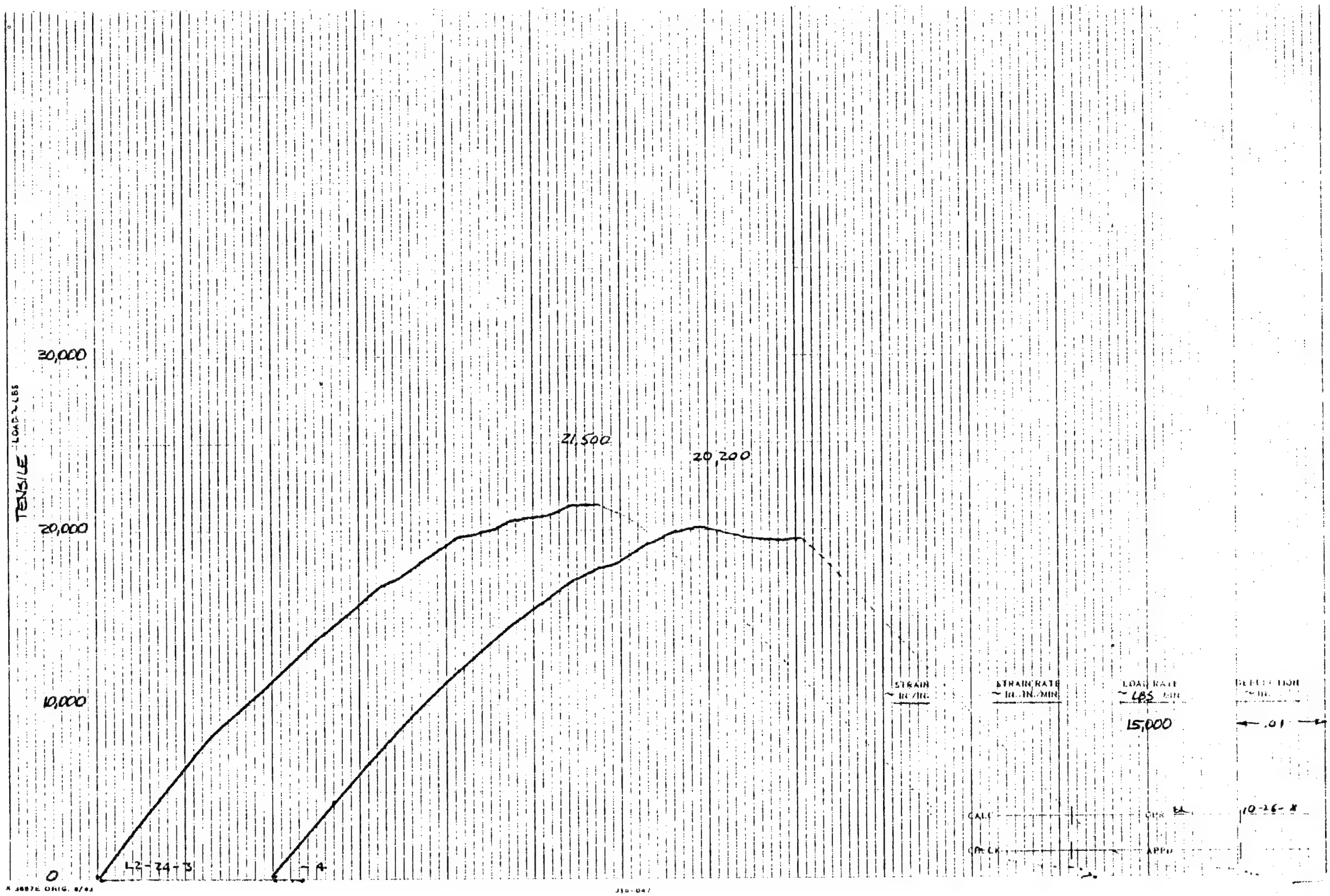


AFTER MOISTURE CONDITIONING





20,000
16,000
12,000
8000
4000
0
TENSILE
L2-24-1
-4
-1
0
-2
4167
8333
12,500
16,667
20834
25,000
20,200
20,200
29,000
25,900
LBS
15,000
.005
6-12-78
OK


TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
21,500
20,200
L2-24-3
-4
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS/MIN
15,000
DEFLECTION ~ IN
.01
CALC
CHECK
CHK
APPD
10-26-

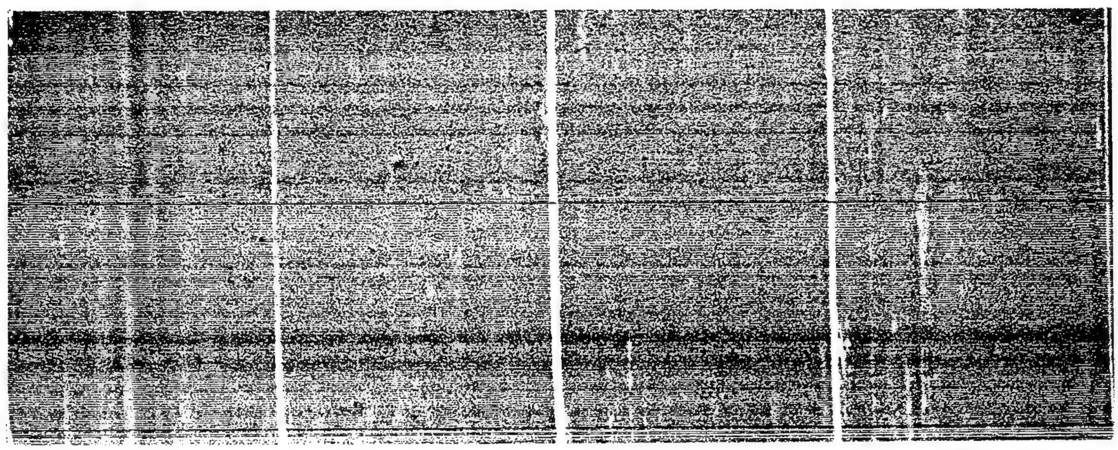
LAMINATE L3
NO DEFECT

TEST SPECIMENS

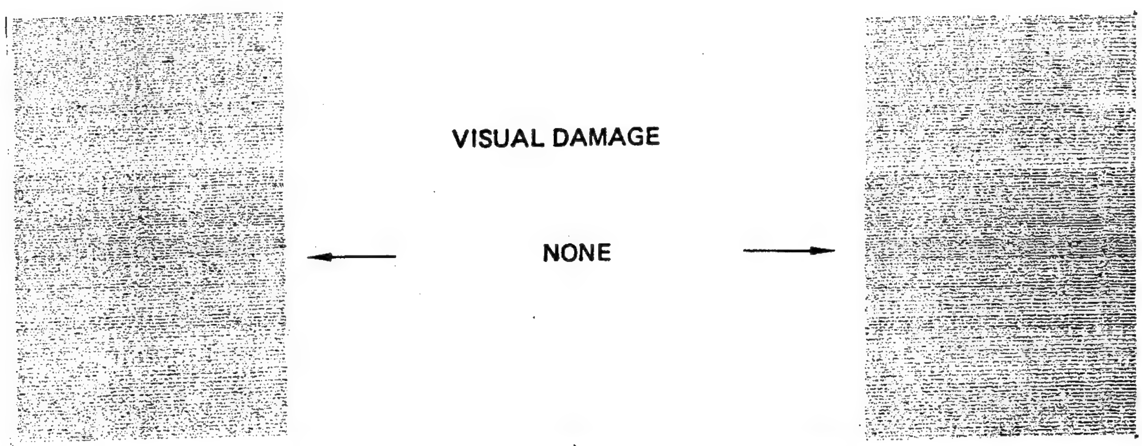
ROOM TEMPERATURE | 422° K (300° F)

L3-21-61 | L3-21-62 | L3-21-63 | L3-21-64

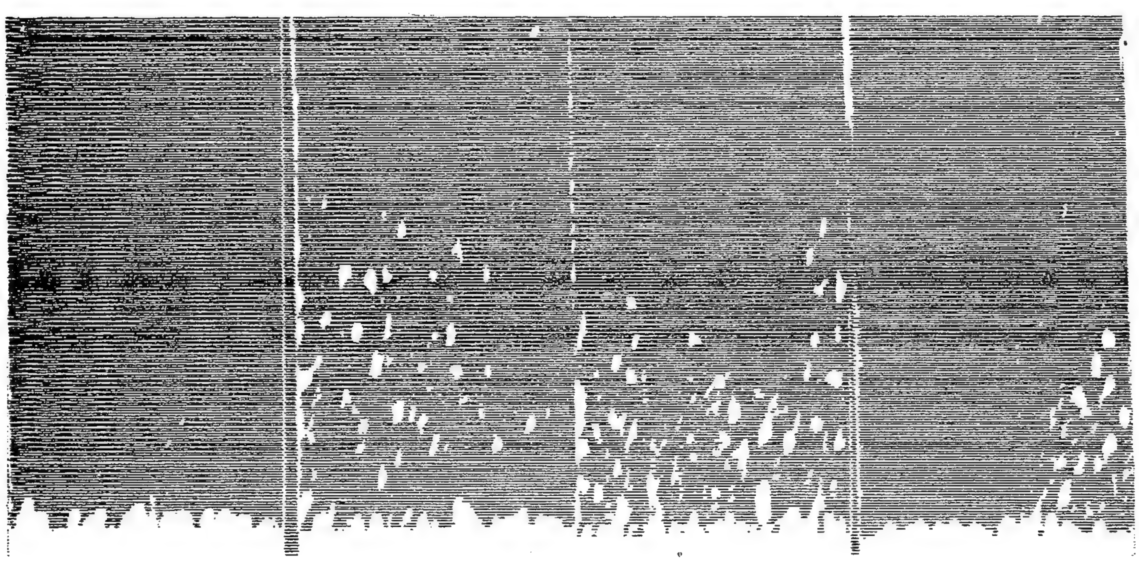
INITIAL

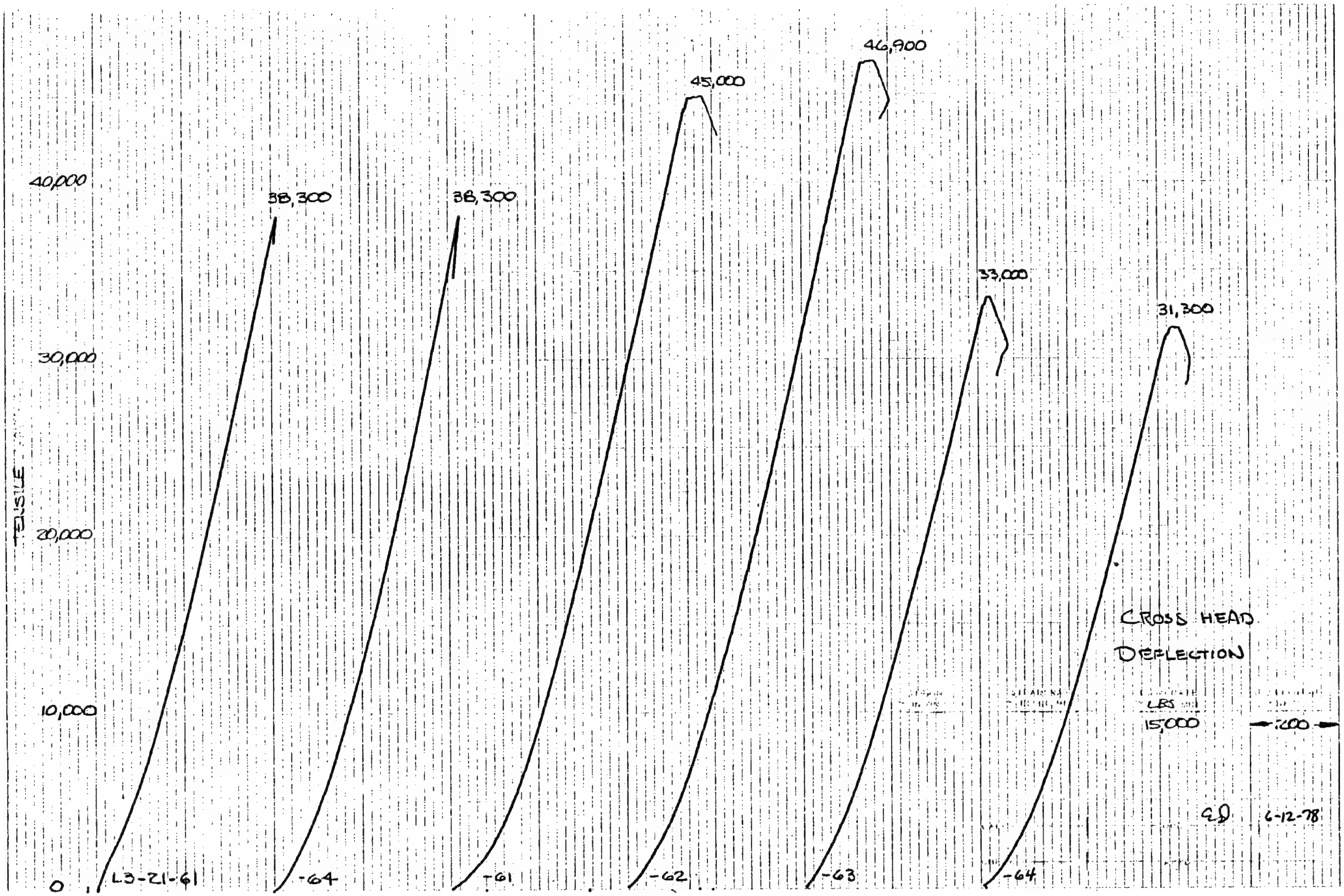


AFTER PRELOAD 38.3 KIP



AFTER MOISTURE CONDITIONING




TENSILE
40,000
30,000
20,000
10,000
0
38,300
38,300
45,000
46,900
33,000
31,300
L3-21-61
-64
-61
-62
-63
-64
CROSS HEAD
DEFLECTION
LBS
15,000
.200
6-12-78

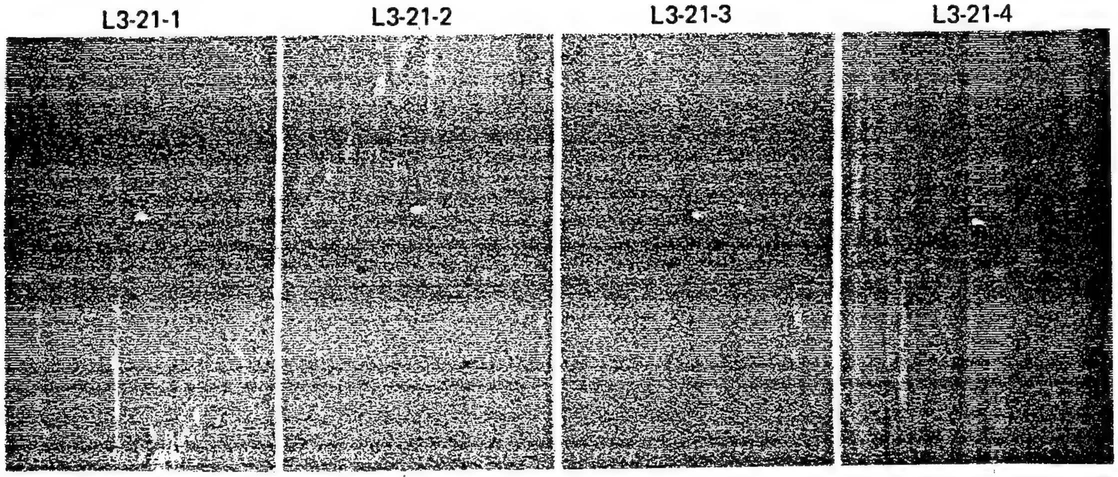
LAMINATE L3
1/8 FP SLIT

TEST SPECIMENS

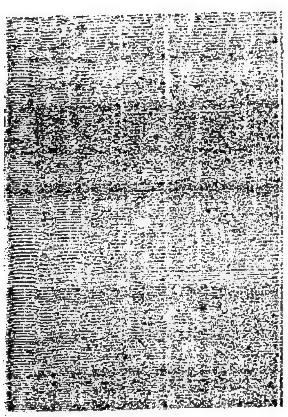
ROOM TEMPERATURE | 422° K (300° F)

L3-21-1 | L3-21-2 | L3-21-3 | L3-21-4

INITIAL

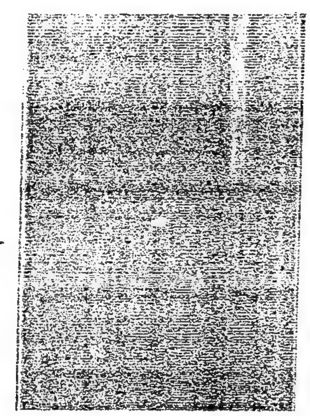


AFTER PRELOAD 23.6 KIP

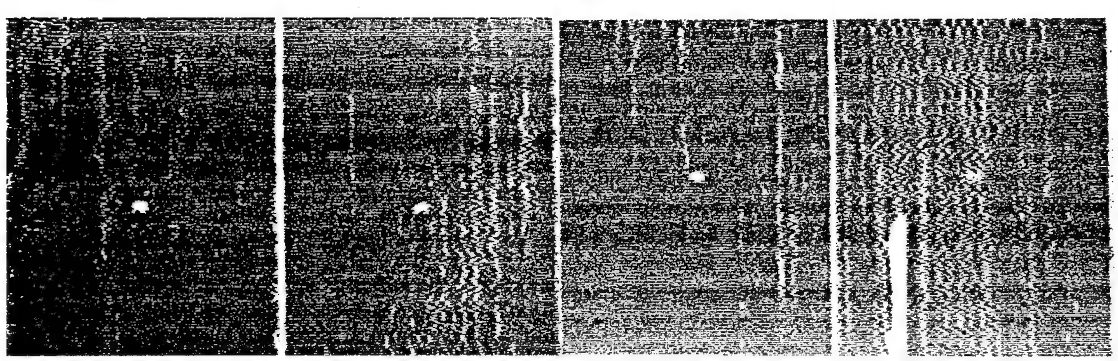


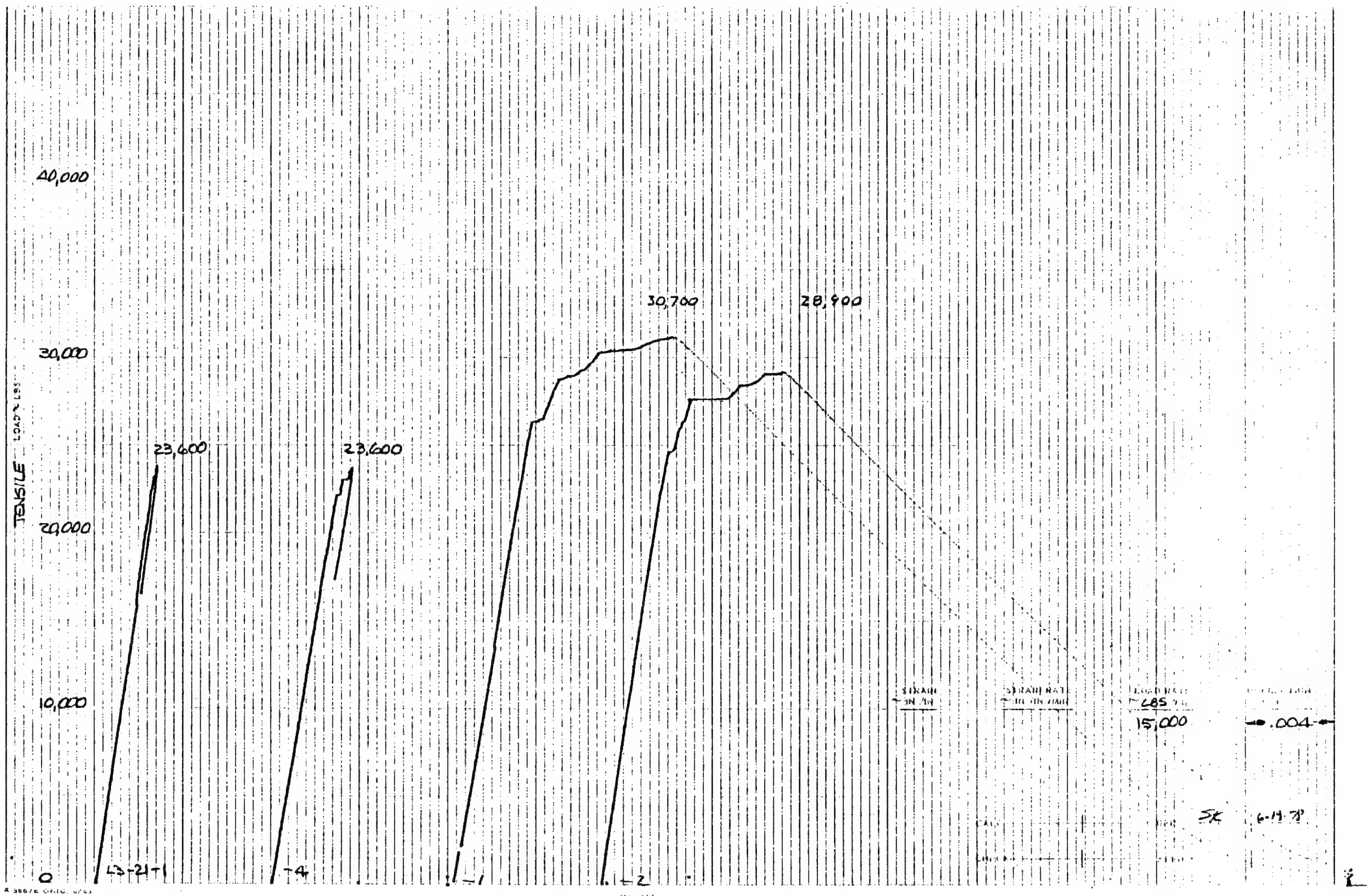
VISUAL DAMAGE

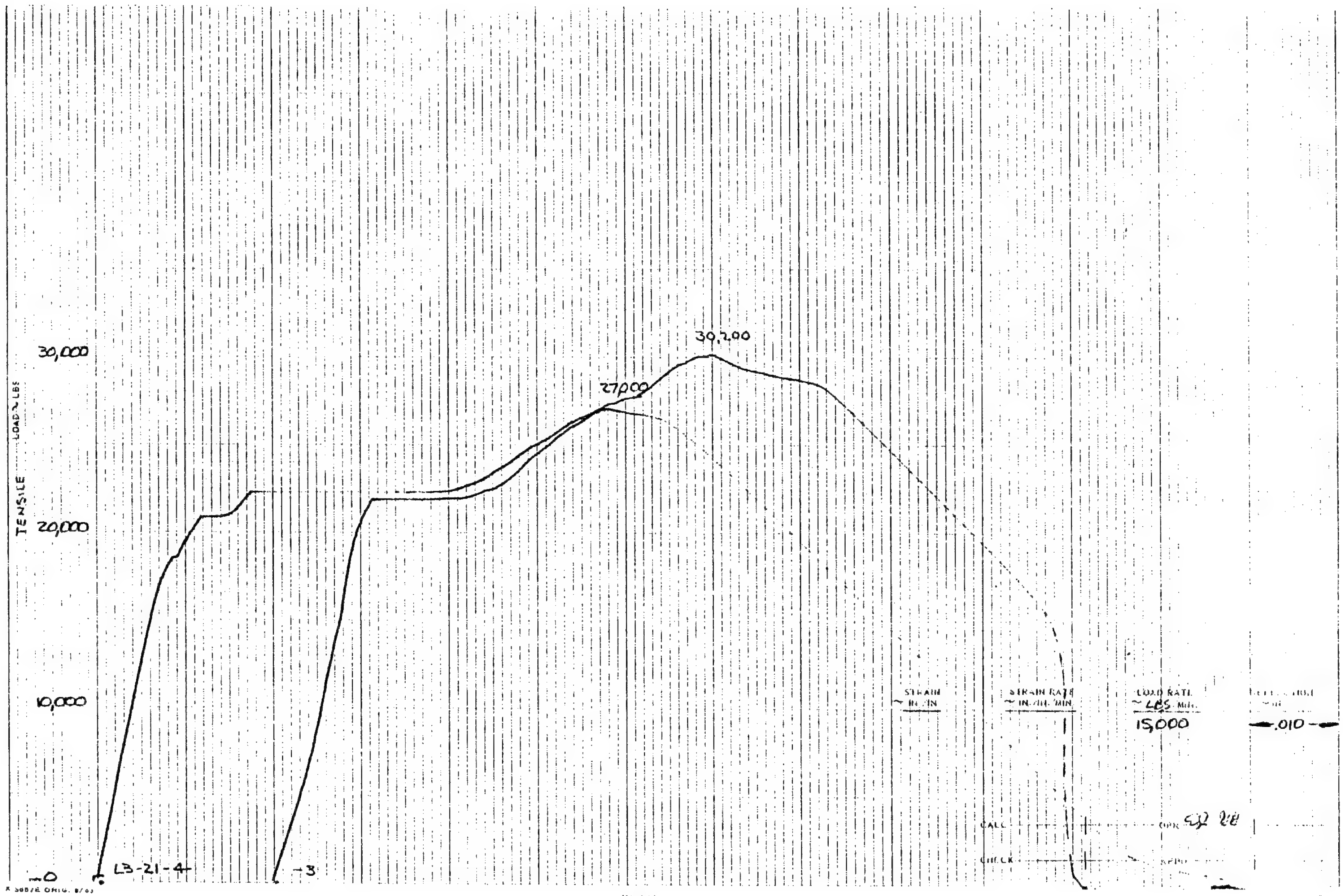
← NONE →



AFTER MOISTURE CONDITIONING




TENSILE
LOAD LBS
40,000
30,000
20,000
10,000
0
23,600
23,600
30,700
28,900
L3-21-1
-4
-1
-2
STRAIN IN/IN
STRAIN RATE IN/IN/MIN
LOAD RATE LBS
15,000
.004
SK
6-19-78



TENSILE
LOAD ~ LBS
30,000
20,000
10,000
0
L3-21-4
-3
27,000
30,200
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS MIN
15,000
.010
CALL
CHECK
OPR

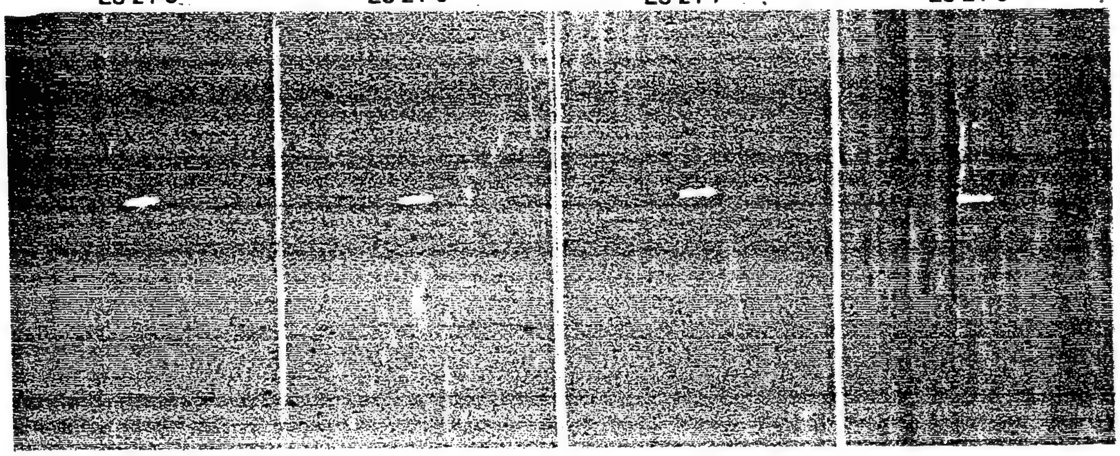
LAMINATE L3
3/8 FP SLIT

TEST SPECIMENS

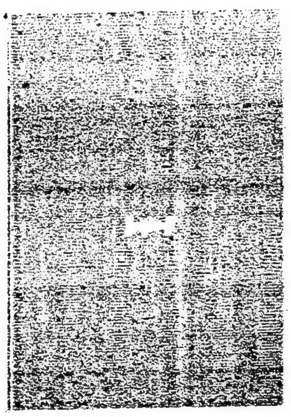
ROOM TEMPERATURE | 422° K (300° F)

L3-21-5 | L3-21-6 | L3-21-7 | L3-21-8

INITIAL

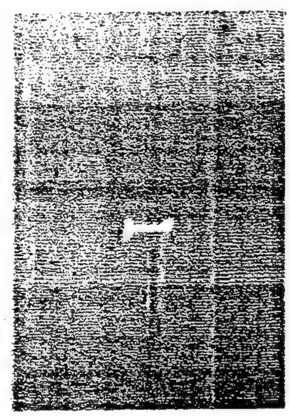


AFTER PRELOAD
18.3 KIP

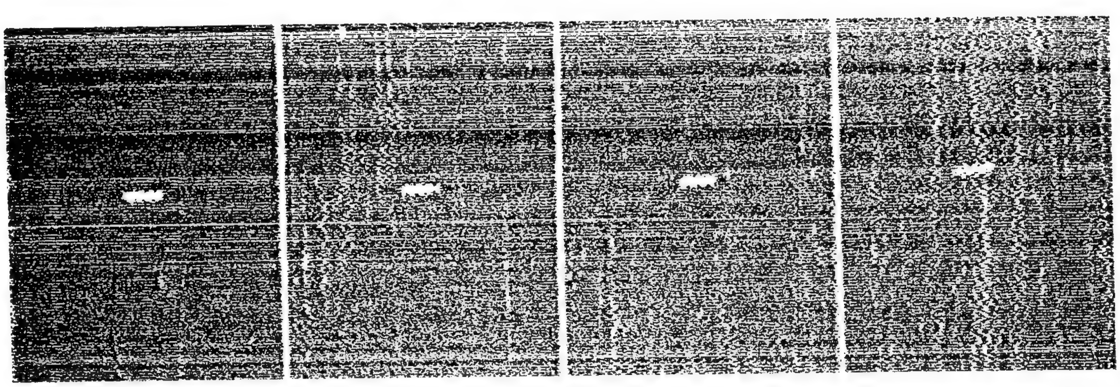


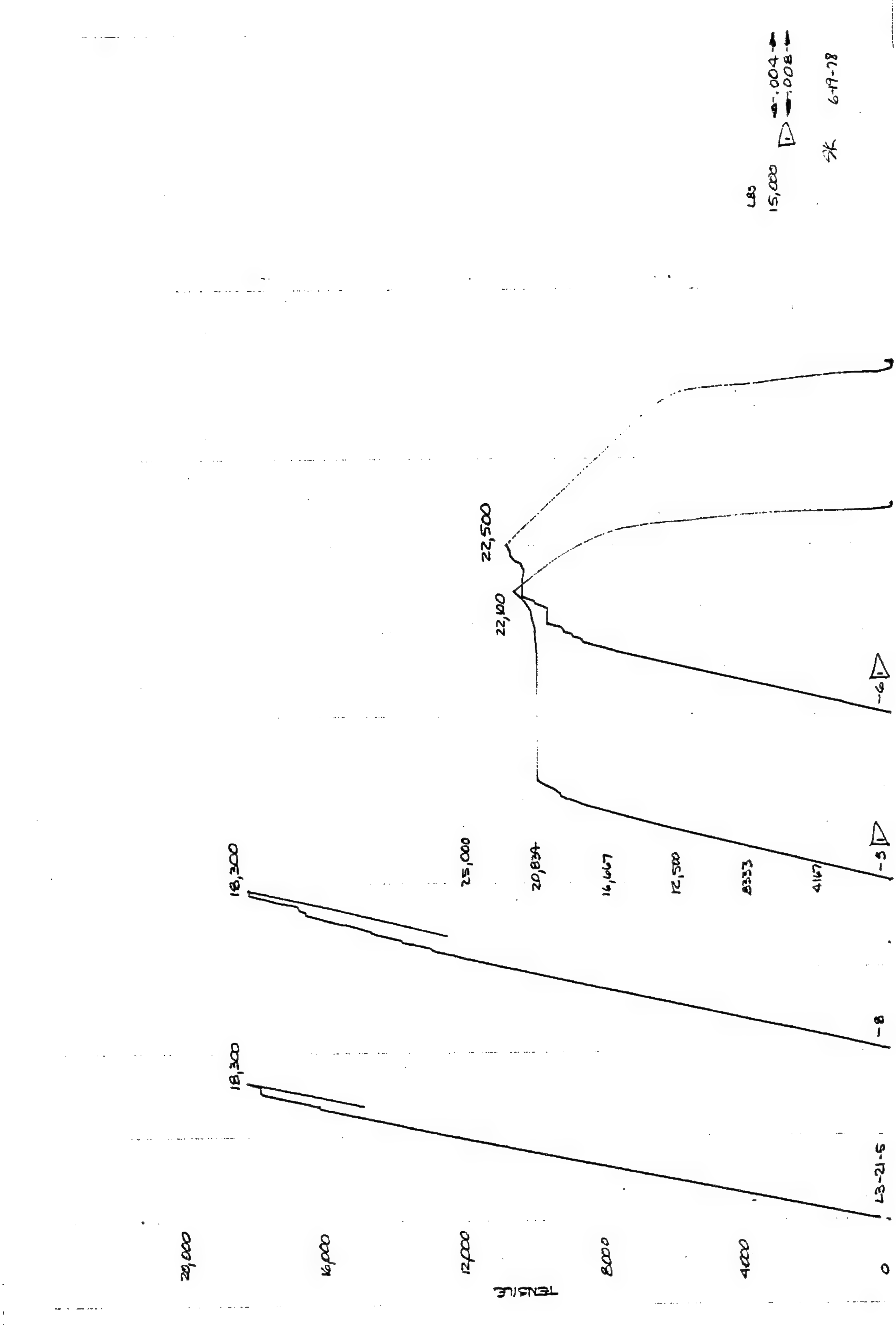
VISUAL DAMAGE

← NONE →

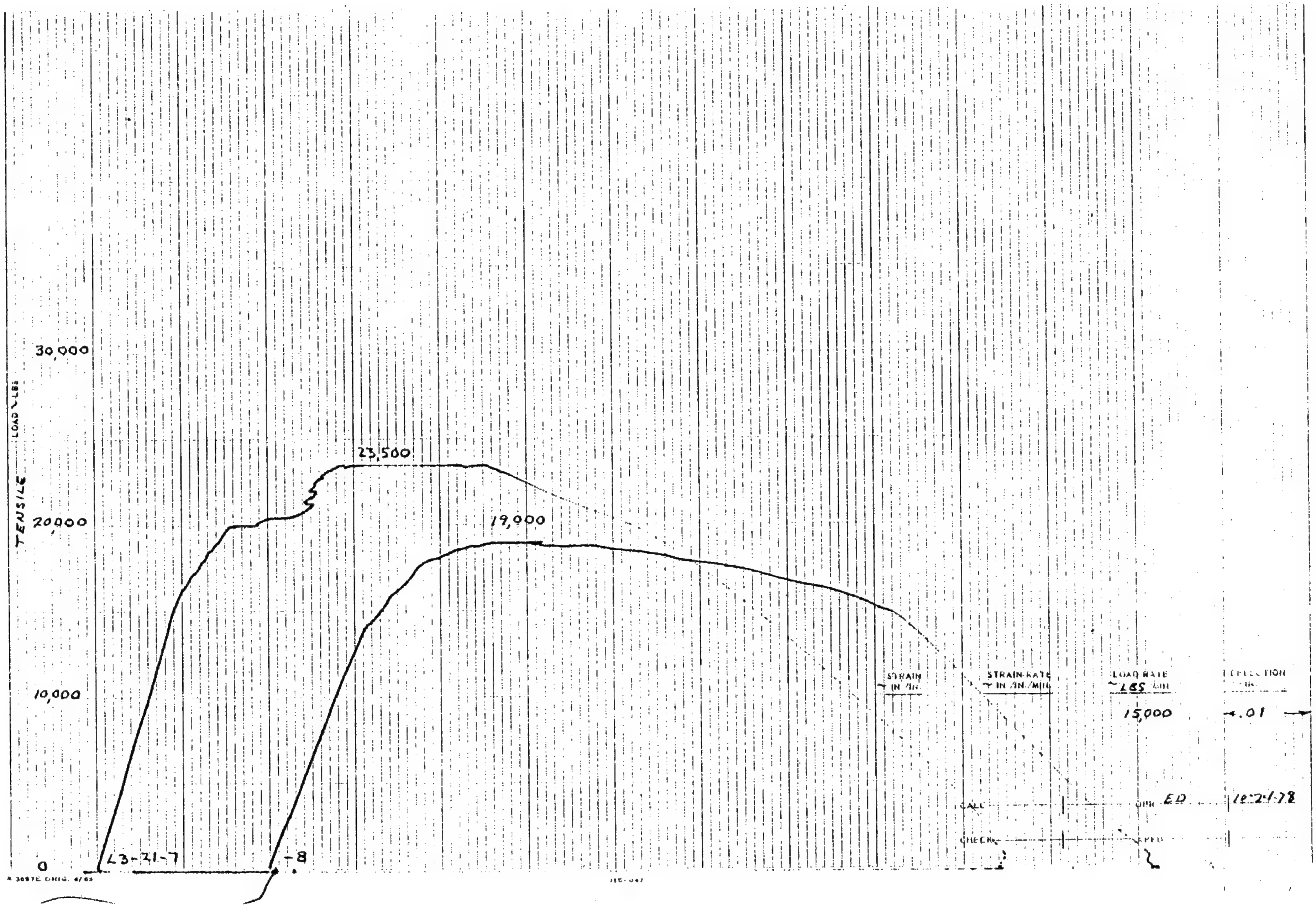


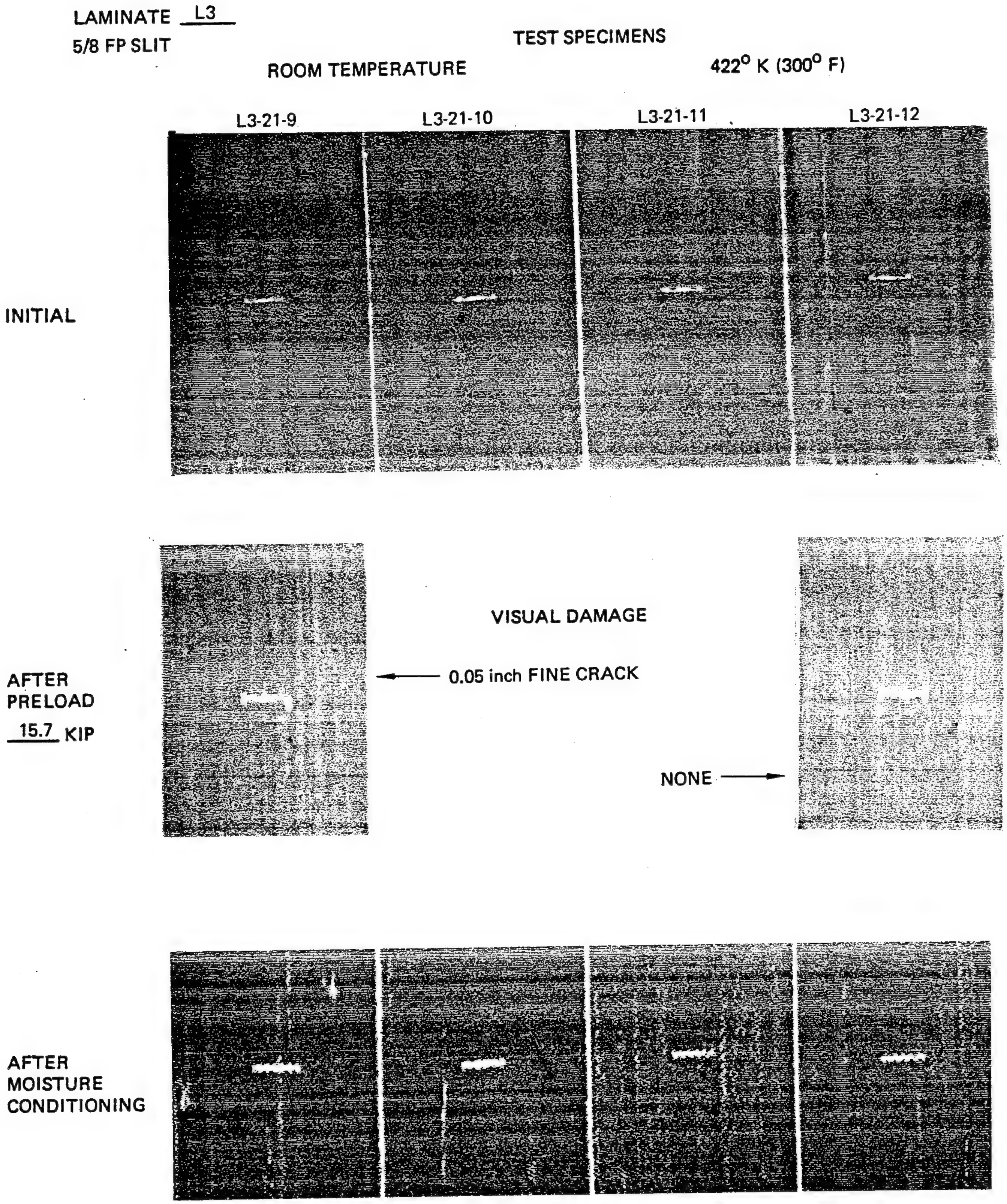
AFTER MOISTURE CONDITIONING

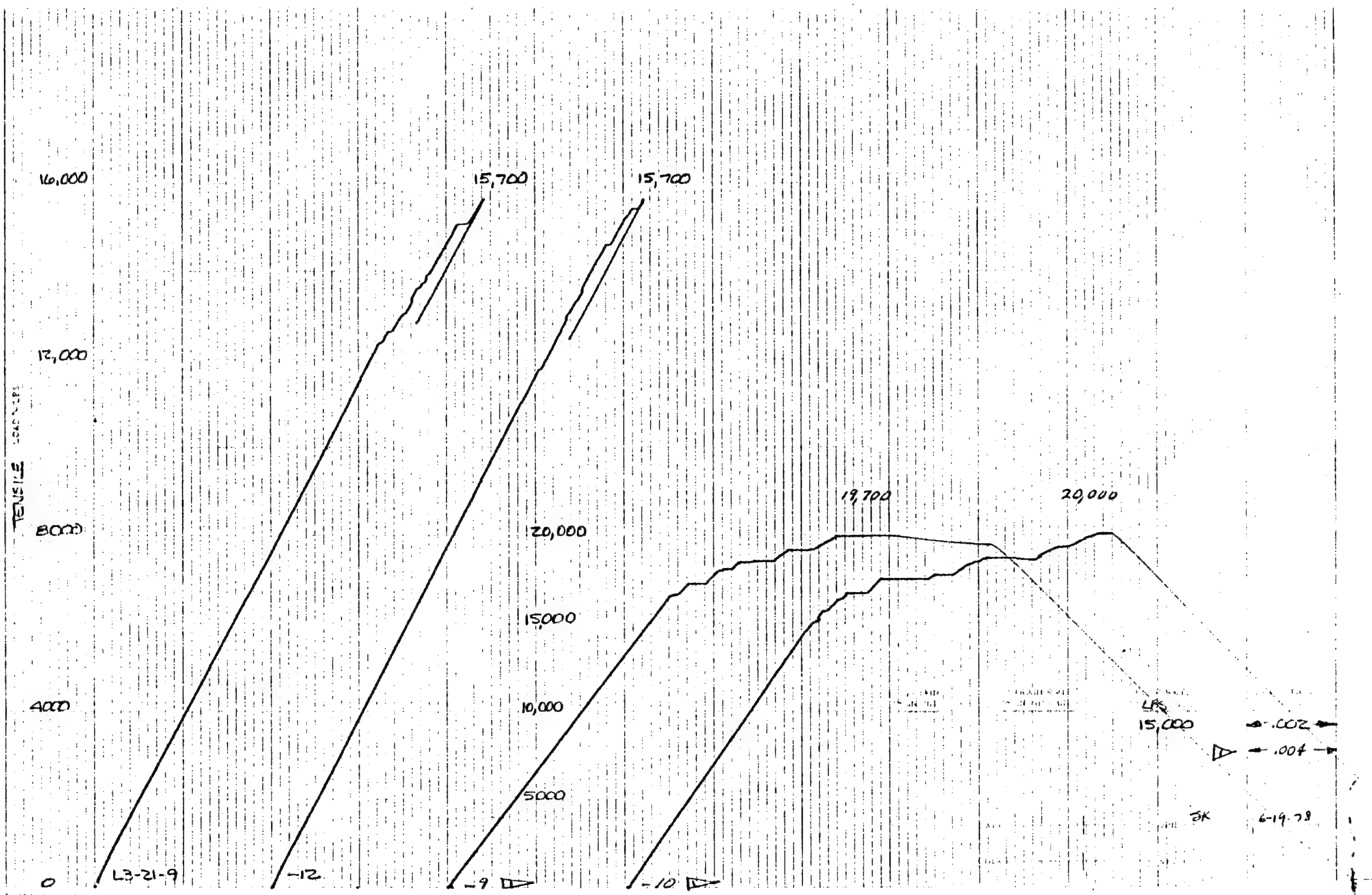


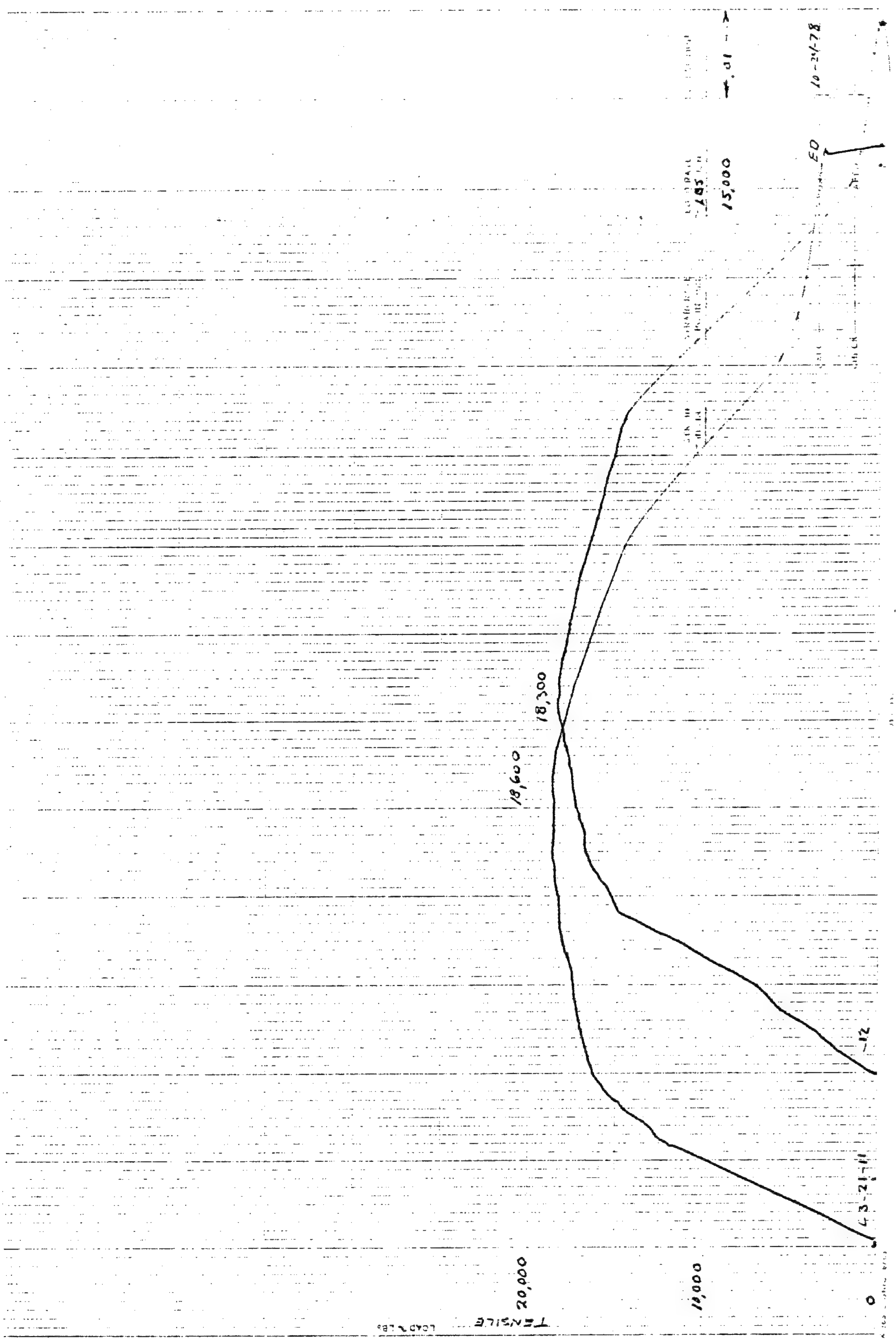


LBS
15,000
.004
.008
SK 6-19-78
22,500
22,100
-6
-5
25,000
20,834
16,667
12,500
8333
4167
18,300
-8
18,300
L3-21-5
20,000
16,000
12,000
8000
4000
0
TENSILE


TENSILE
LOAD ~ LBS
30,000
20,000
10,000
0
23,500
19,000
L3-31-7
-8
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE ~ LBS./MIN.
15,000
DEFLECTION ~ IN.
.01
CALC
CHK. ED
10-24-78
CHECK
APPD


LAMINATE L3
5/8 FP SLIT
TEST SPECIMENS
ROOM TEMPERATURE
422° K (300° F)
L3-21-9
L3-21-10
L3-21-11
L3-21-12
INITIAL
VISUAL DAMAGE
AFTER PRELOAD 15.7 KIP
0.05 inch FINE CRACK
NONE
AFTER MOISTURE CONDITIONING


16,000
12,000
8000
4000
0
TENSILE
15,700
15,700
L3-21-9
-12
-9
-10
20,000
15,000
10,000
5000
19,700
20,000
LR
15,000
.002
.004
JK
6-19-78



TENSILE
LOAD ~ LBS
20,000
10,000
0
18,300
18,600
15,000
10-24-78
43-21-11
-12
ED

LAMINATE L3

1/8 HP SLIT

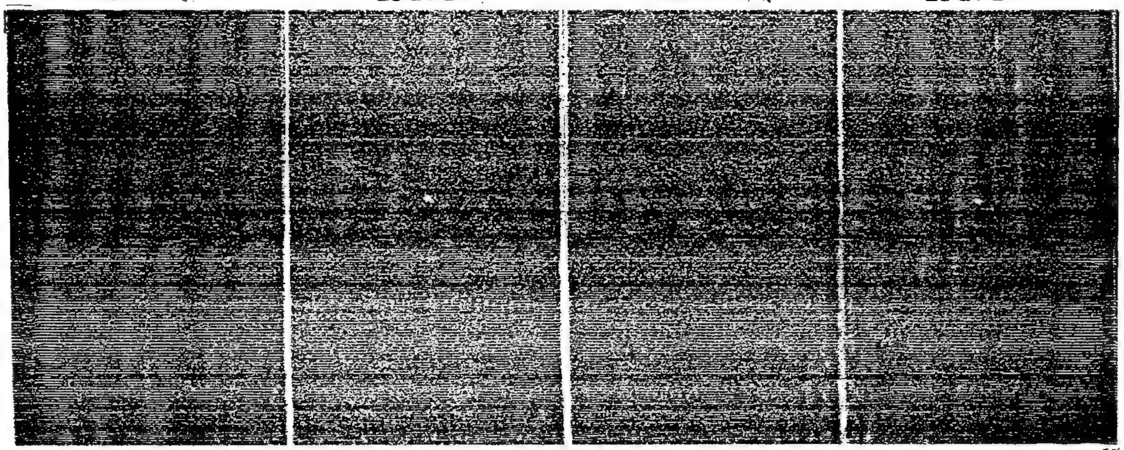
TEST SPECIMENS

ROOM TEMPERATURE

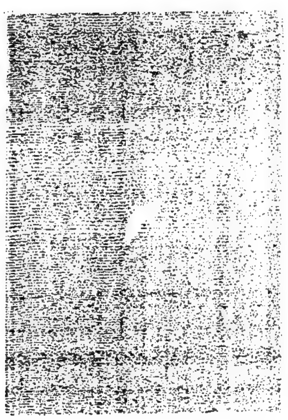
422° K (300° F)

L3-21-21 L3-21-22 L3-21-23 L3-21-24

INITIAL

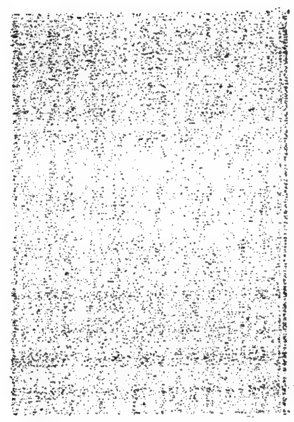


AFTER PRELOAD 30.3 KIP

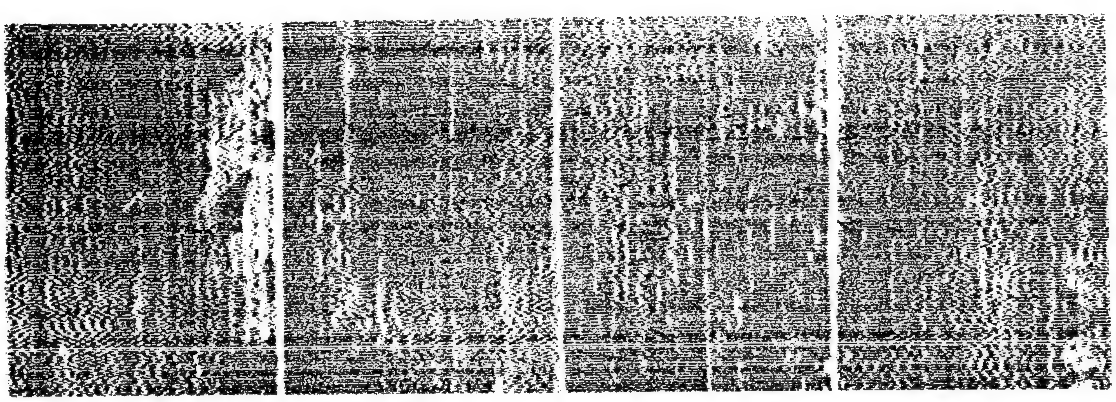


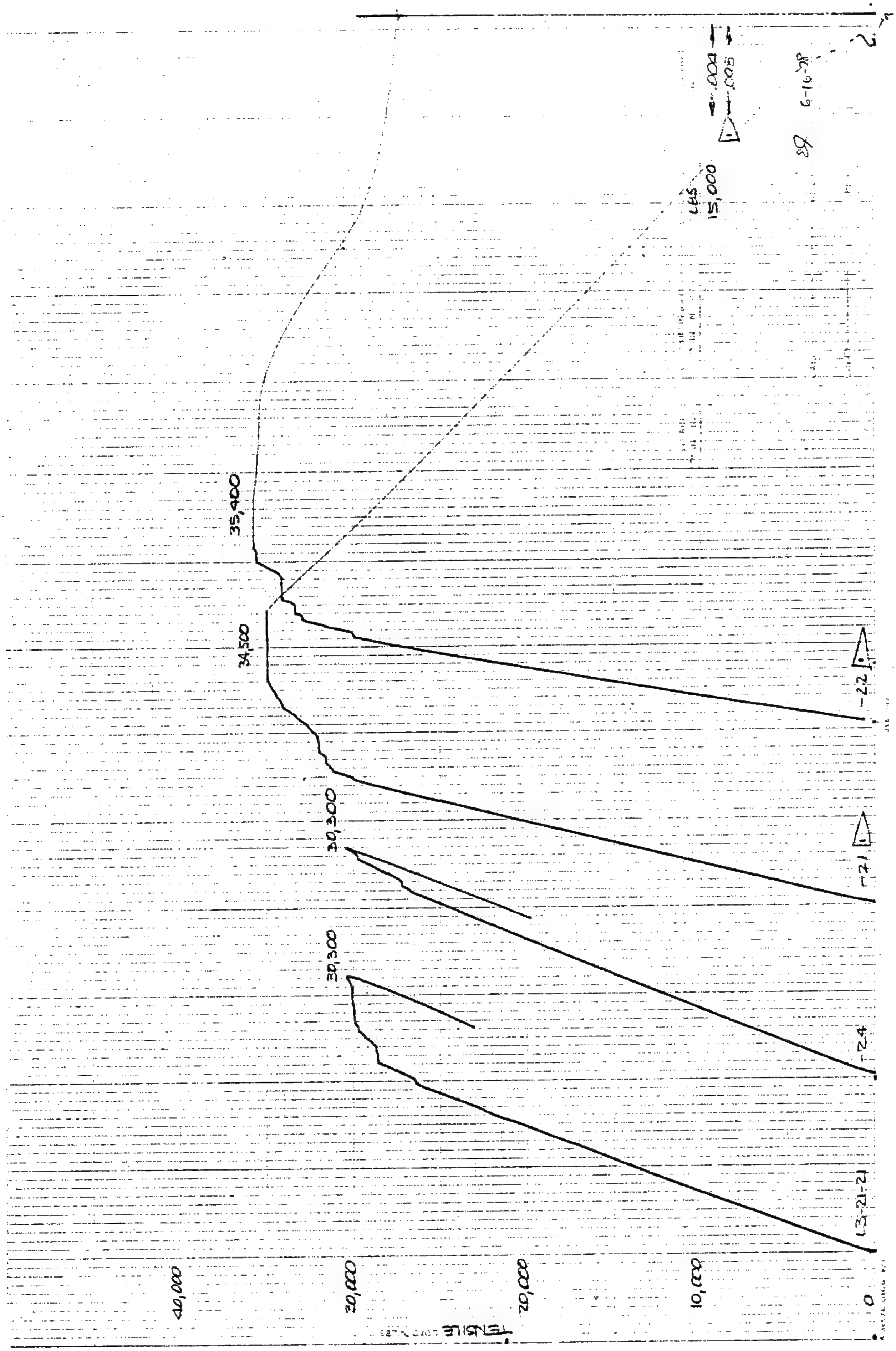
VISUAL DAMAGE

NONE

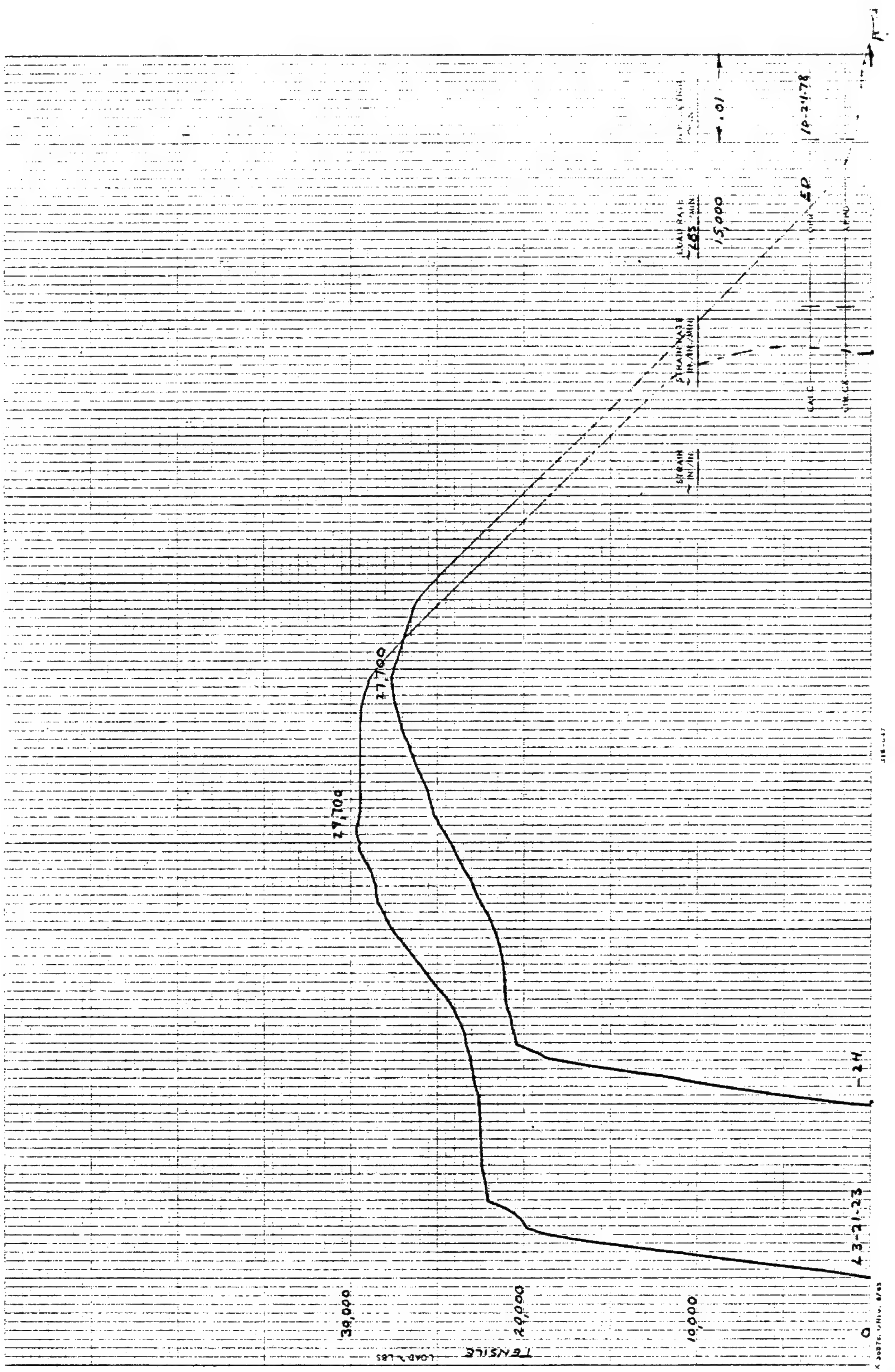


AFTER MOISTURE CONDITIONING





TENSILE
40,000
30,000
20,000
10,000
0
35,400
34,500
30,300
30,300
-2.2
-21
-24
L3-21-21
LBS
15,000
.004
.005
6-16-78



TENSILE
LOAD ~ LBS
30,000
20,000
10,000
0
43-21-23
2H
29,100
27,700
STRAIN ~ IN/IN
STRAIN RATE ~ IN/IN/MIN
LOAD RATE ~ LBS/MIN
15,000
.01
10-24-78
ED

LAMINATE L3
3/8 HP SLIT

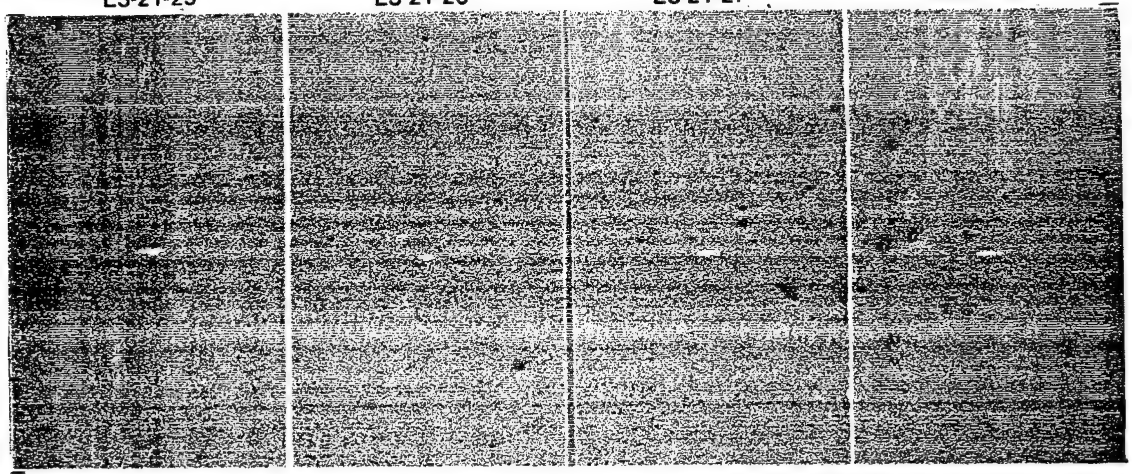
TEST SPECIMENS

ROOM TEMPERATURE

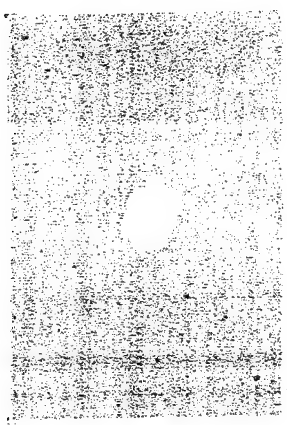
422° K (300° F)

L3-21-25 L3-21-26 L3-21-27 L3-21-28

INITIAL

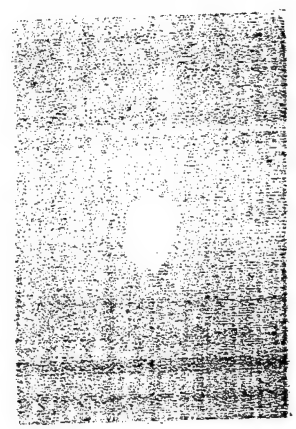


AFTER PRELOAD
28.8 KIP

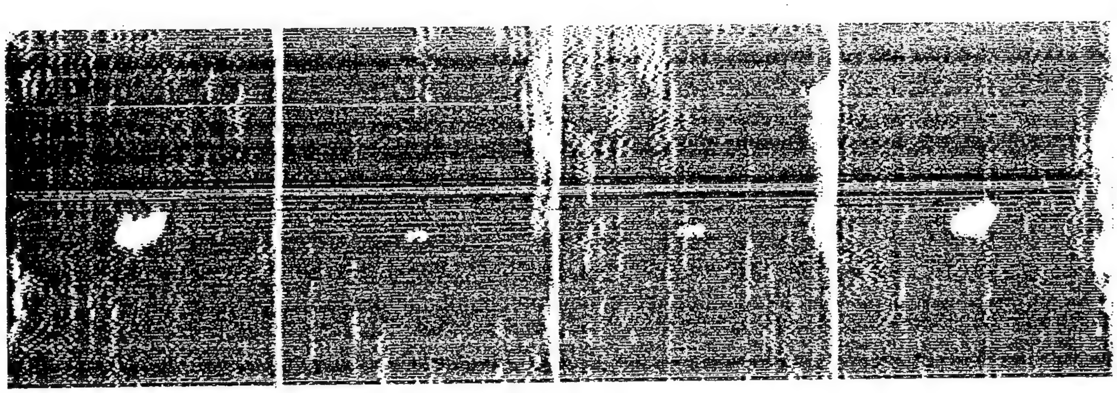


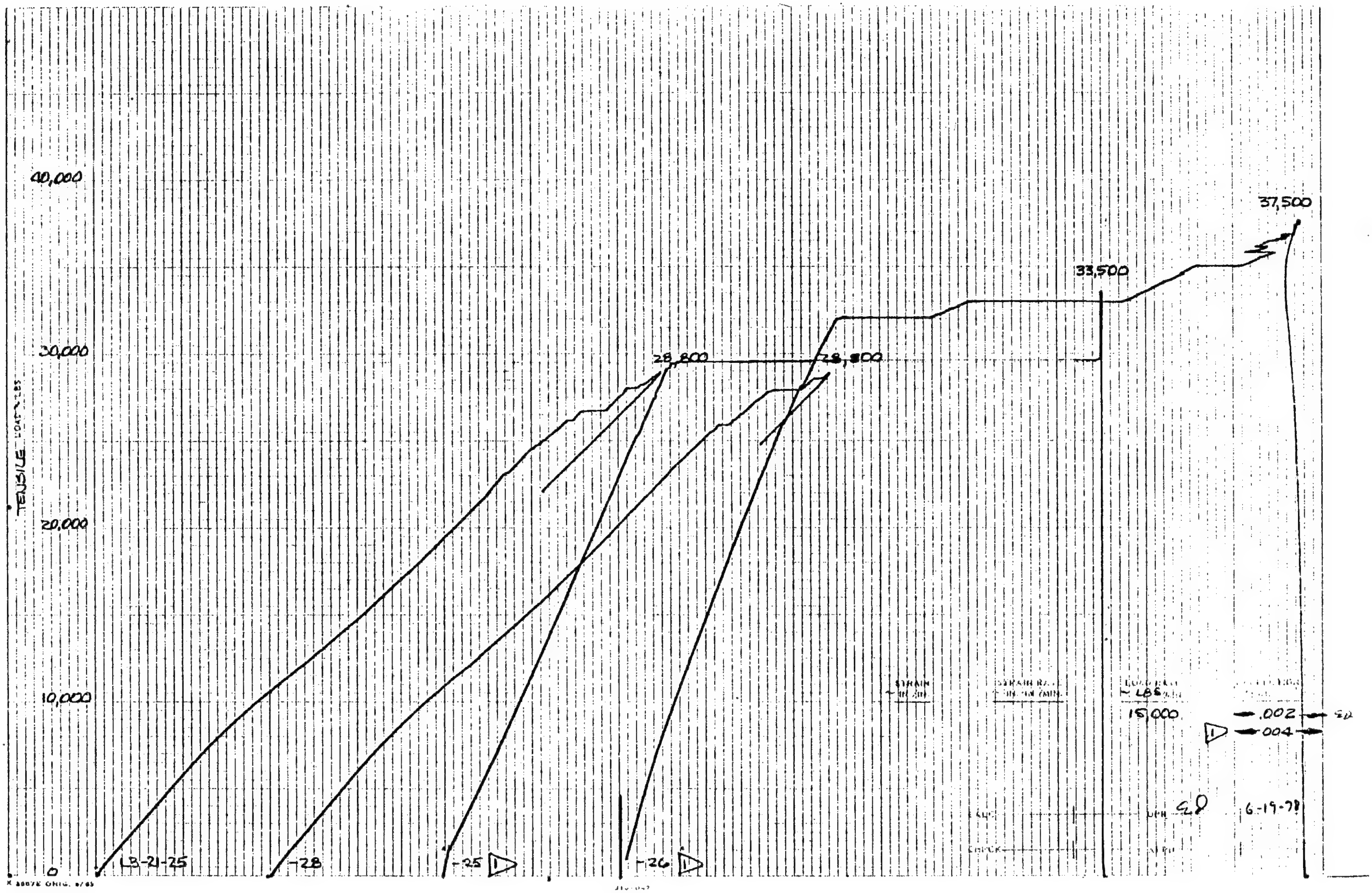
VISUAL DAMAGE

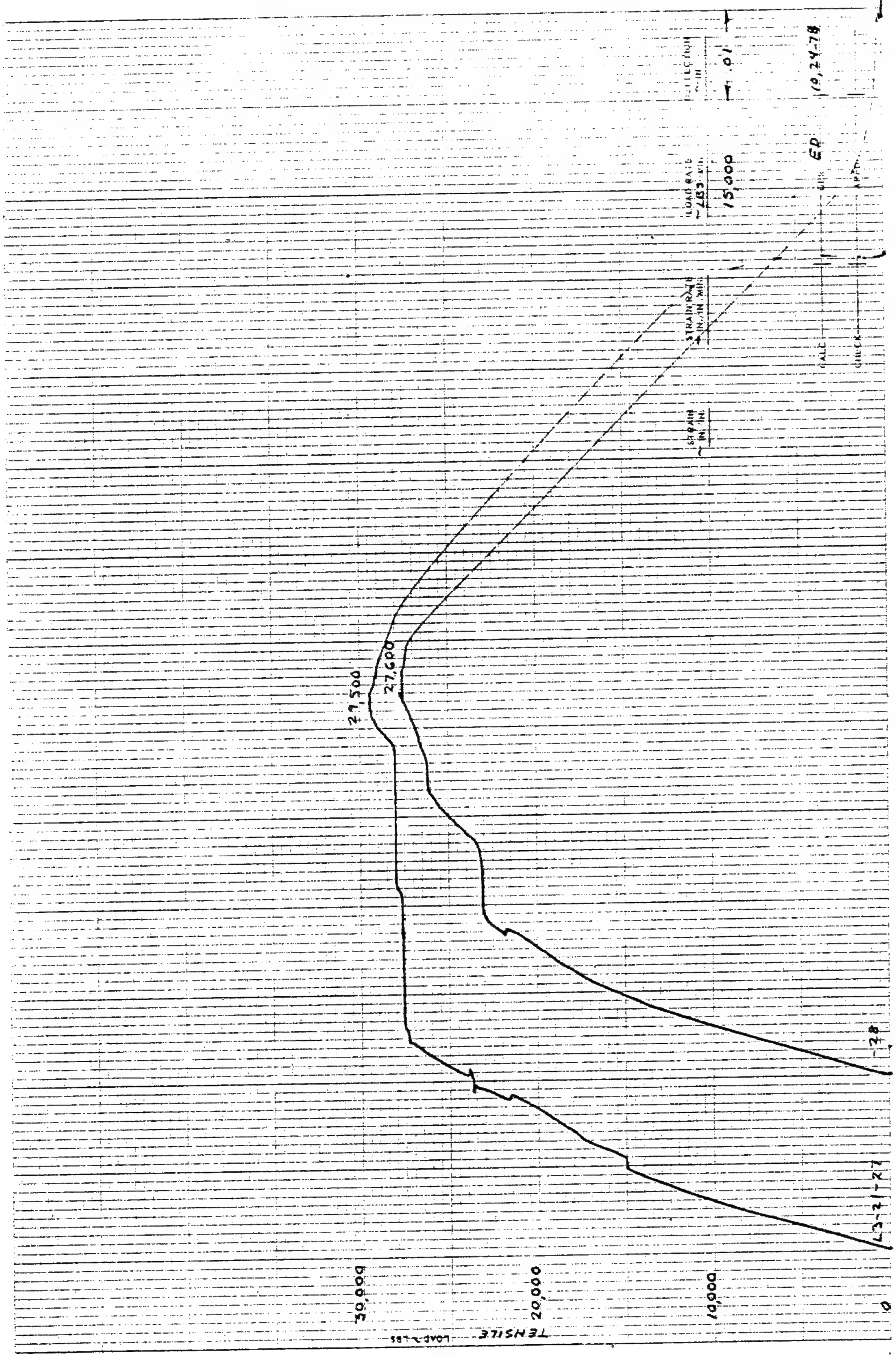
← 0.05–0.1 inch FINE CRACKS →



AFTER MOISTURE CONDITIONING




40,000
30,000
20,000
10,000
0
TENSILE
37,500
33,500
28,800
28,800
LB-21-25
-28
-25
-26
15,000
.002
.004
6-19-78


LOAD RATE ~ LBS MIN
15,000
DEFLECTION ~ IN
.01
STRAIN RATE ~ IN./IN. MIN.
STRAIN ~ IN./IN.
CALC
ED
10,24-78
CHECK
APPD.
27,500
27,600
LS-21-27
-28
30,000
20,000
10,000
0
TENSILE LOAD ~ LBS

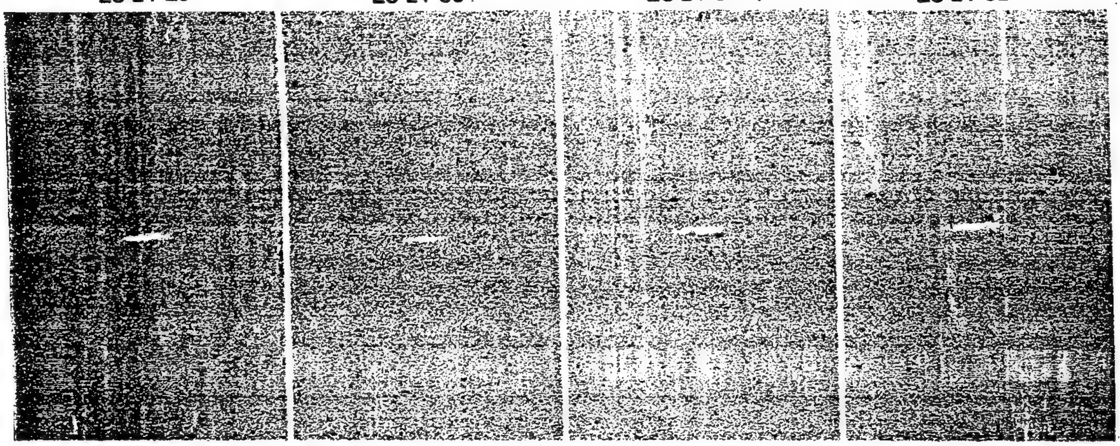
LAMINATE L3
5/8 HP SLIT

TEST SPECIMENS

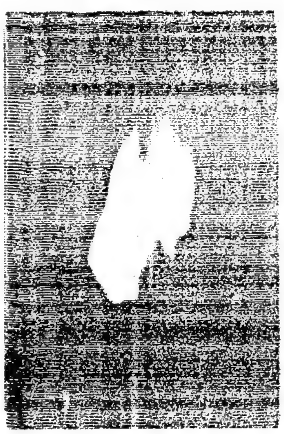
ROOM TEMPERATURE | 422° K (300° F)

L3-21-29 | L3-21-30 | L3-21-31 | L3-21-32

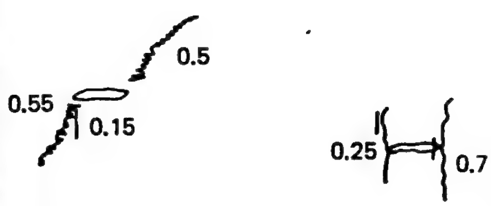
INITIAL

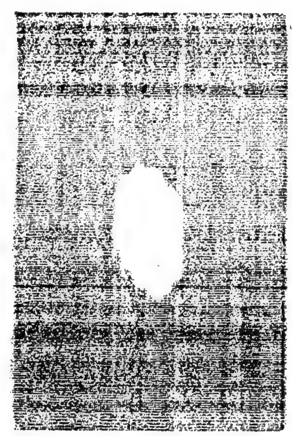


AFTER
PRELOAD
27.5 KIP

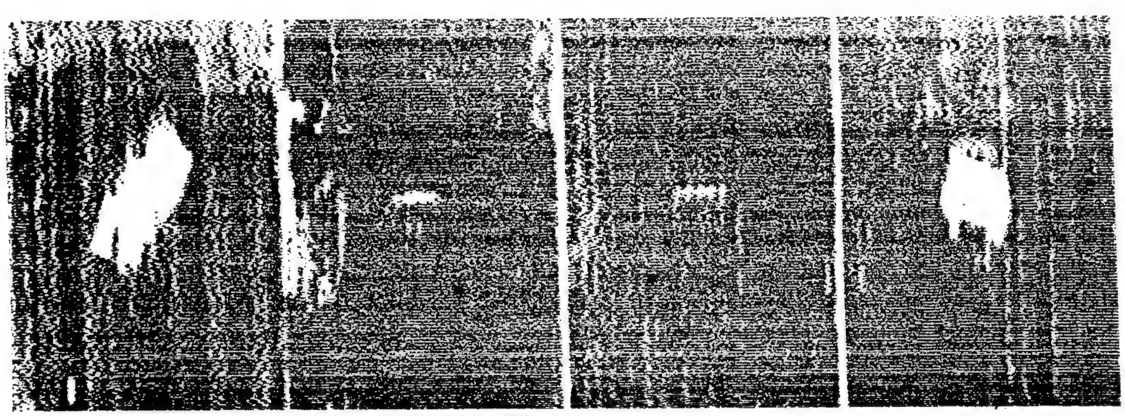


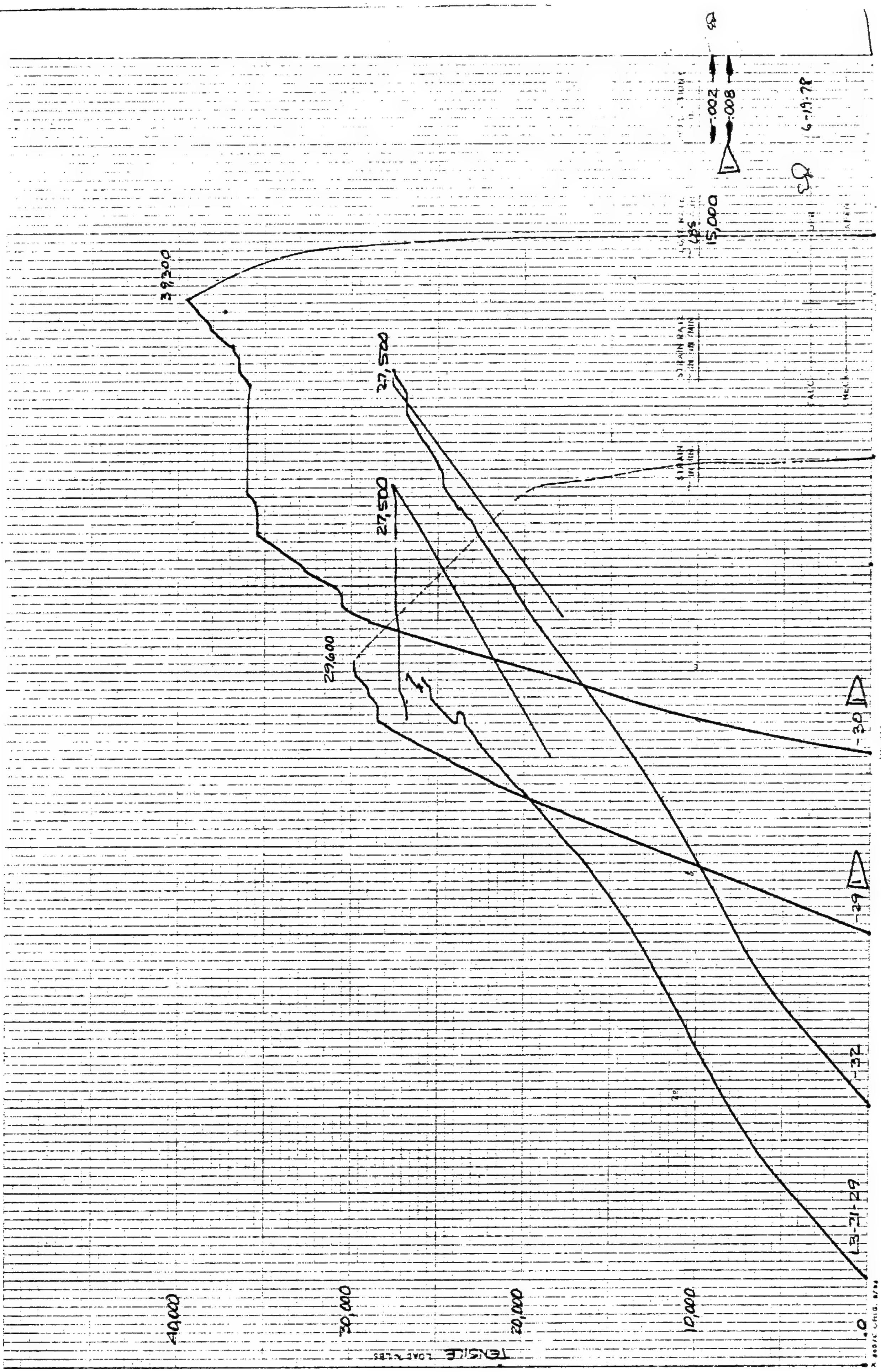
VISUAL DAMAGE

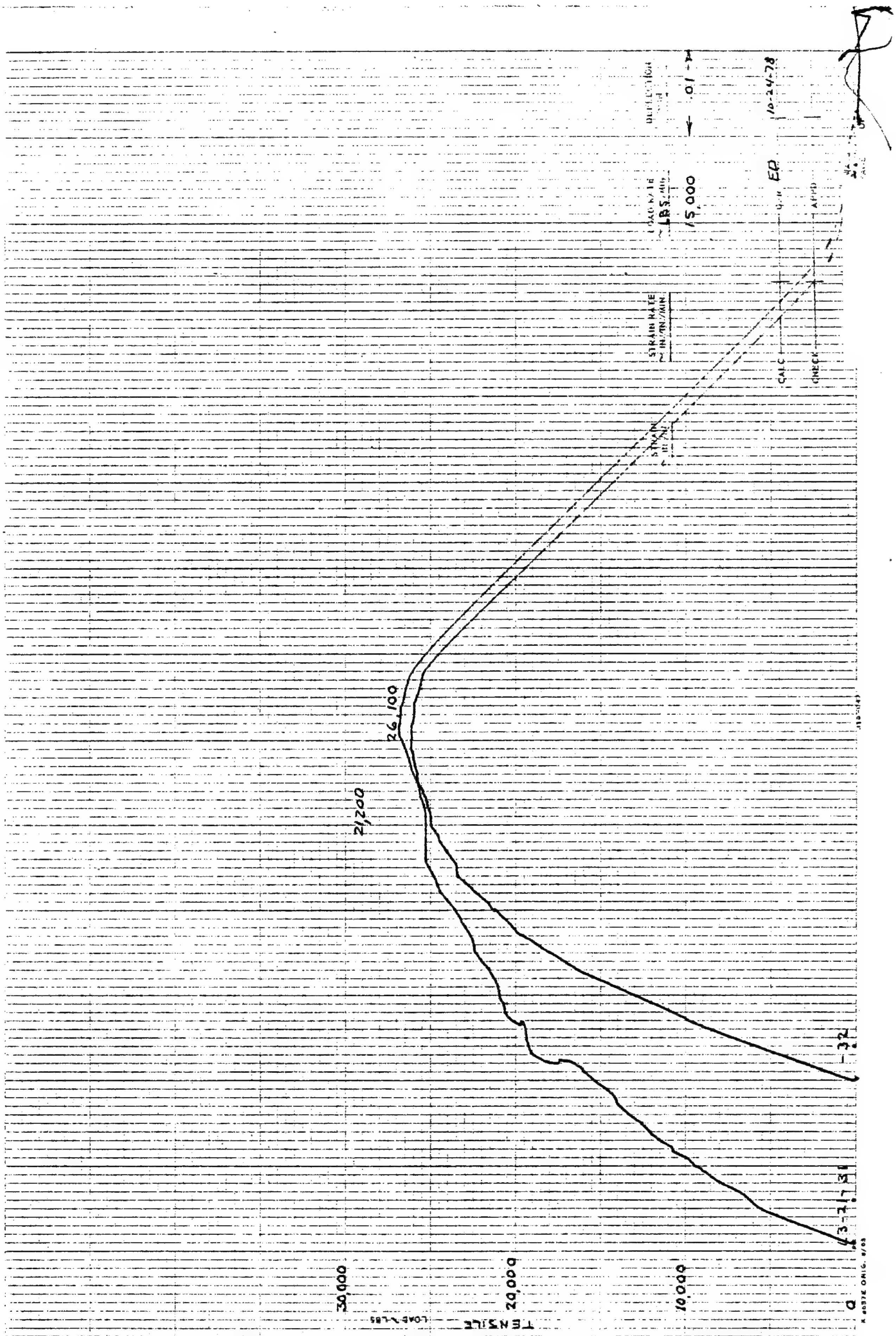


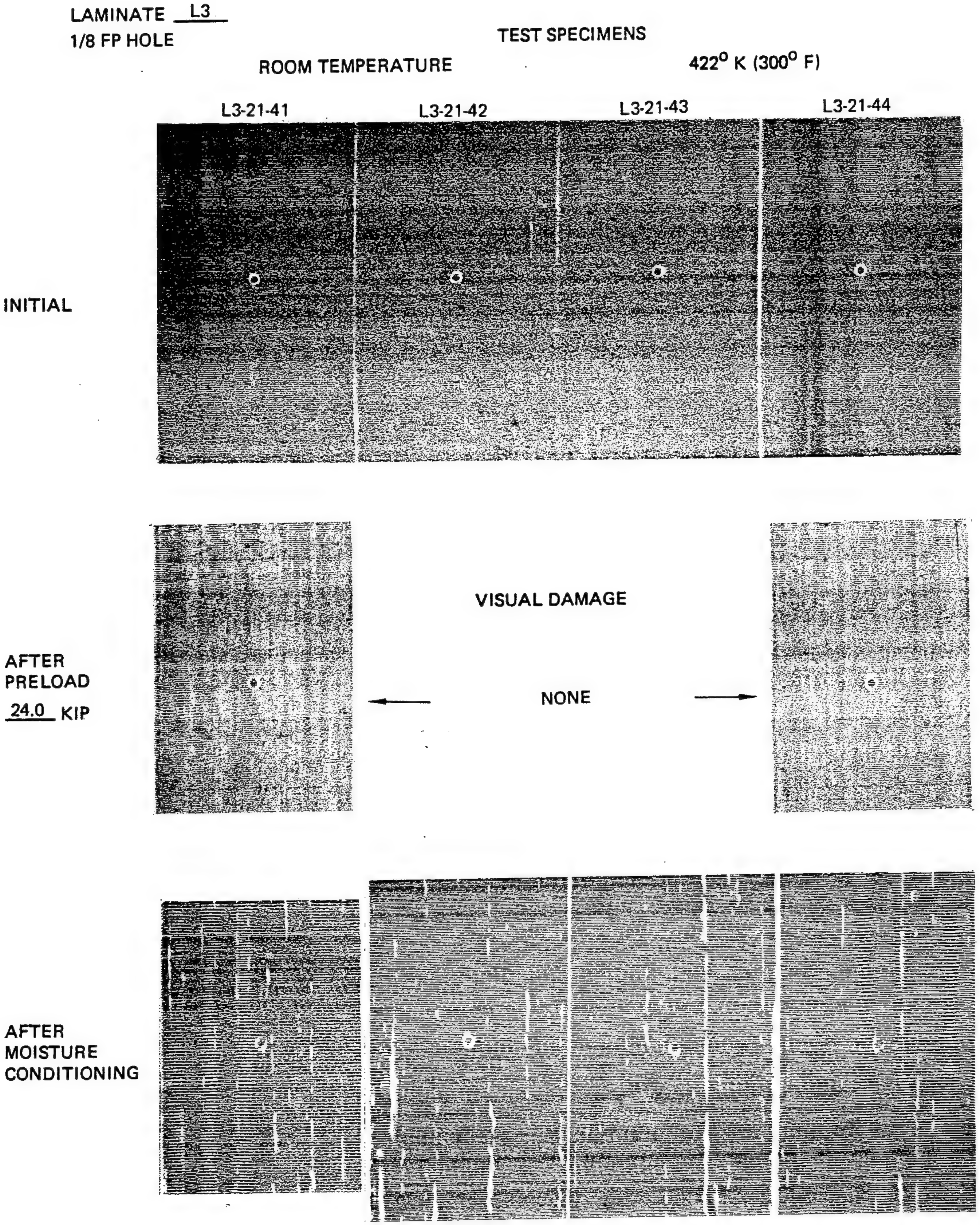


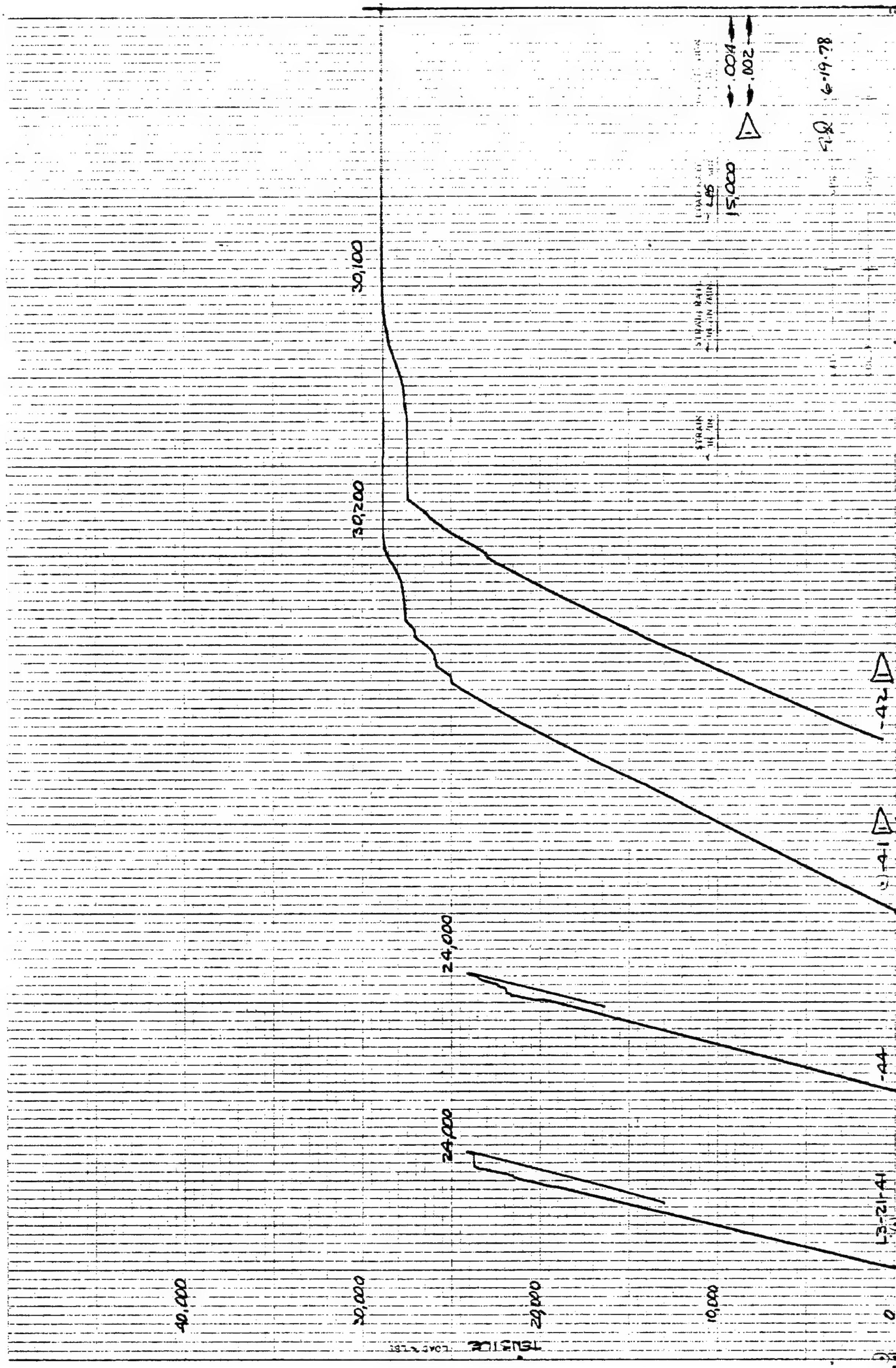
AFTER
MOISTURE
CONDITIONING




TENSILE LOAD-LBS
0
10,000
20,000
30,000
40,000
39300
27,520
27,500
29,600
15,000
.002
.008
6-19-78
L3-21-29
-29
-30
-32

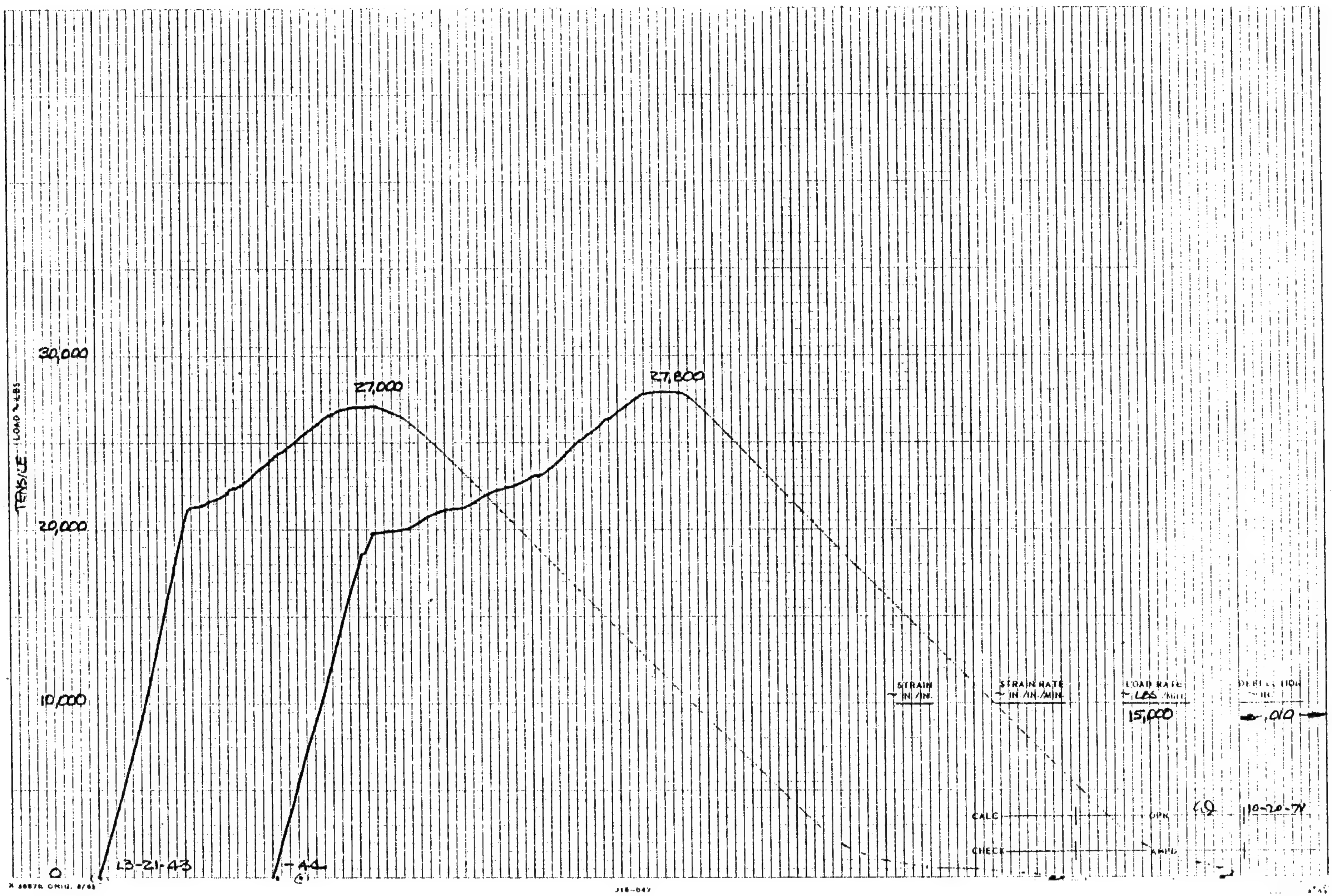

DEFLECTION
.01
LOAD RATE
LBS.
15,000
10-24-78
ED
STRAIN RATE
IN./IN./MIN.
STRAIN
CALC
CHECK
APPD
26,100
21,200
30,000
20,000
10,000
0
TENSILE
LOAD-LBS


LAMINATE L3
1/8 FP HOLE
TEST SPECIMENS
ROOM TEMPERATURE
422° K (300° F)
L3-21-41
L3-21-42
L3-21-43
L3-21-44
INITIAL
VISUAL DAMAGE
AFTER
PRELOAD
24.0 KIP
NONE
AFTER
MOISTURE
CONDITIONING



30,100
30,200
24,000
24,000
L3-21-41
-44
-41
-42
40,000
30,000
20,000
10,000
0
TENSILE
15,000
.004
.002
6-19-78

41 0103



TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
27,000
27,800
L3-21-43
-44
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE ~ LBS/MIN
15,000
DEFLECTION
.010
CALC
CHECK
OPR
APPD
10-20-71

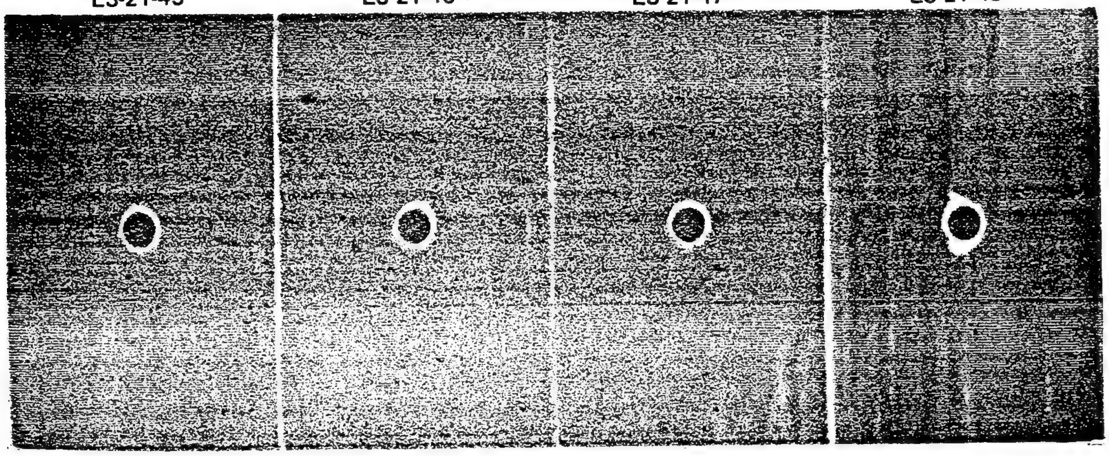
LAMINATE L3
3/8 FP HOLE

TEST SPECIMENS

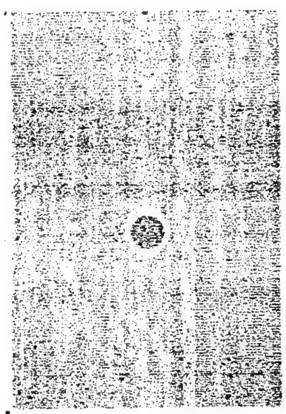
ROOM TEMPERATURE | 422° K (300° F)

L3-21-45 L3-21-46 L3-21-47 L3-21-48

INITIAL

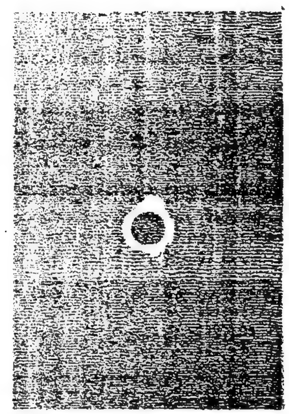


AFTER PRELOAD 18.1 KIP

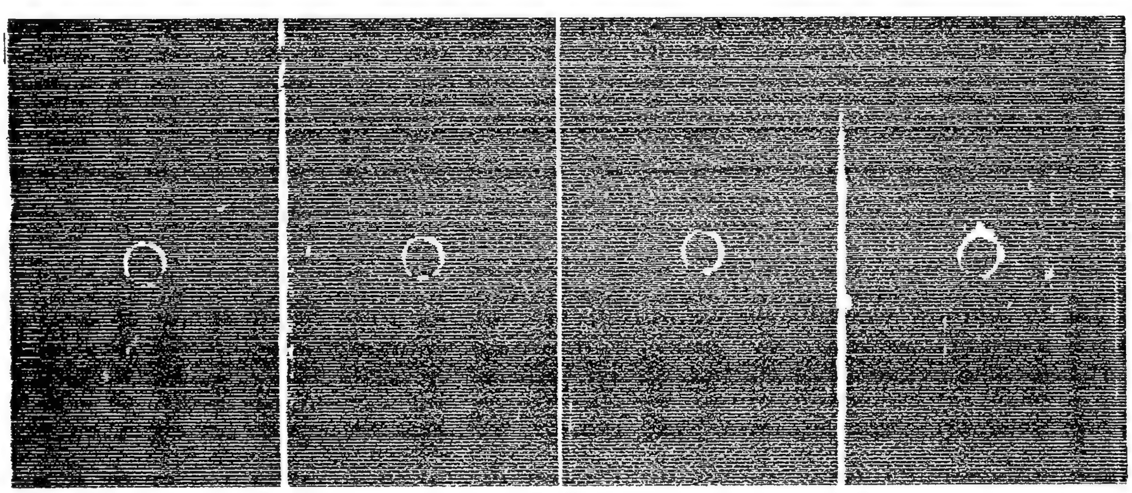


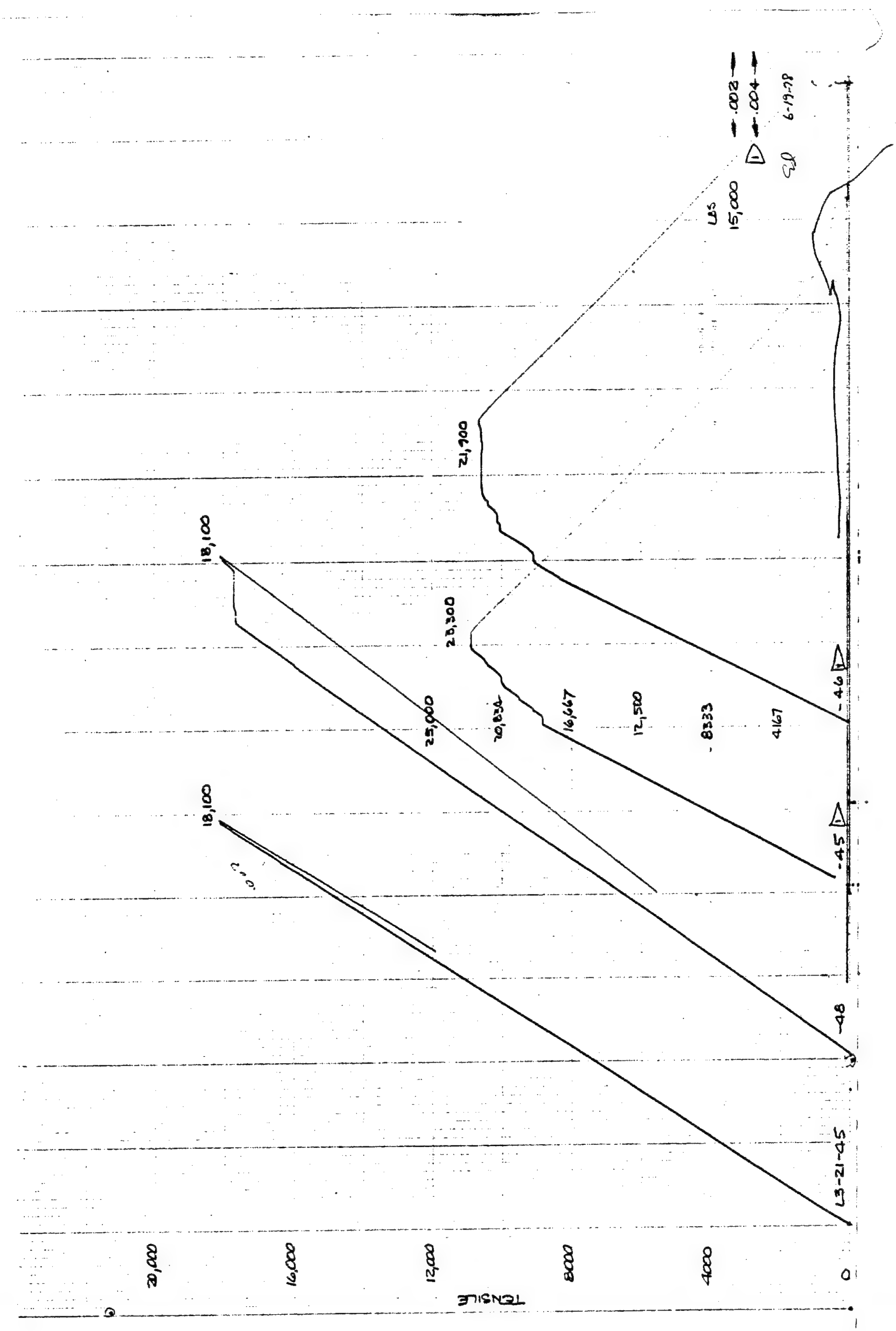
VISUAL DAMAGE

← NONE →

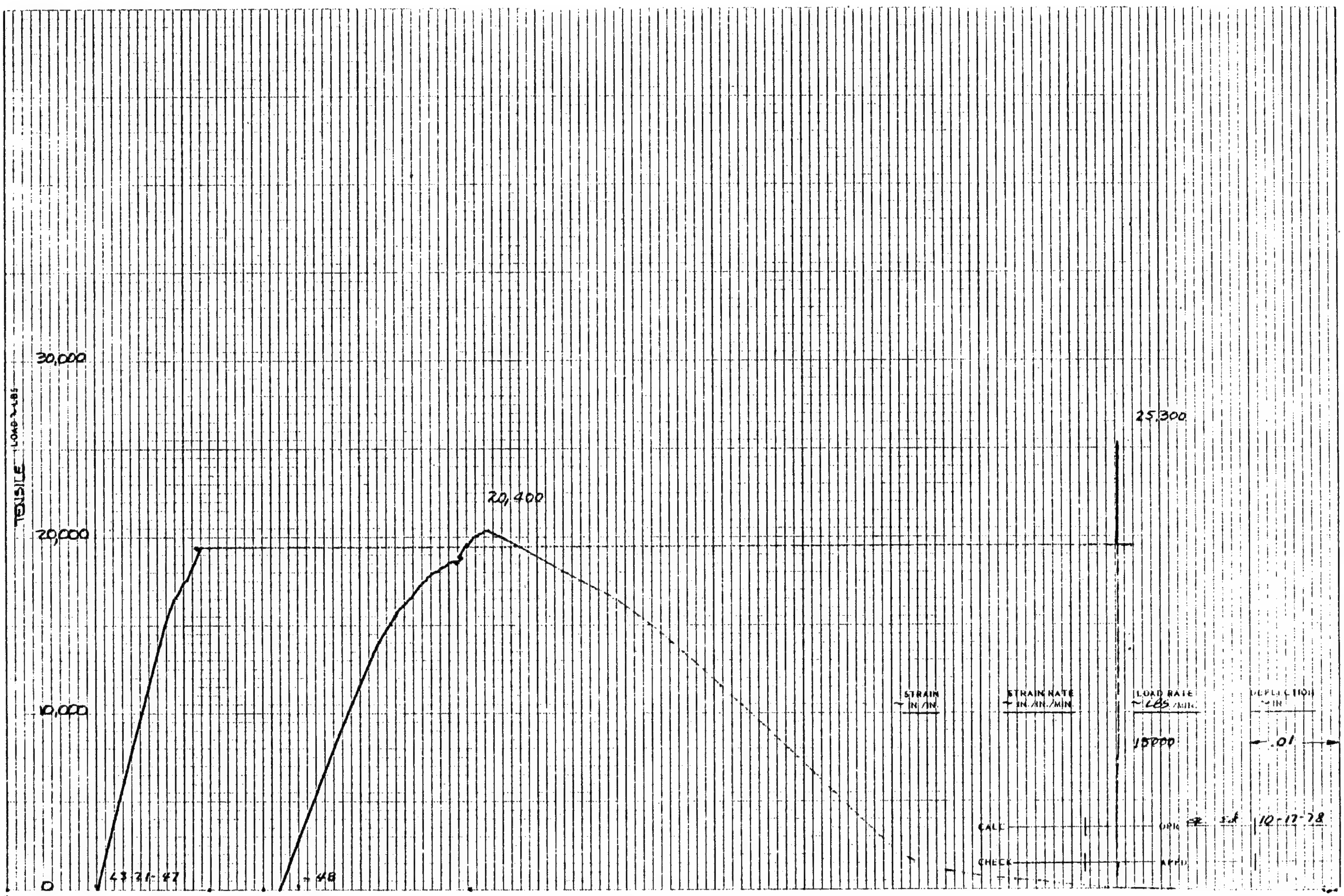


AFTER MOISTURE CONDITIONING



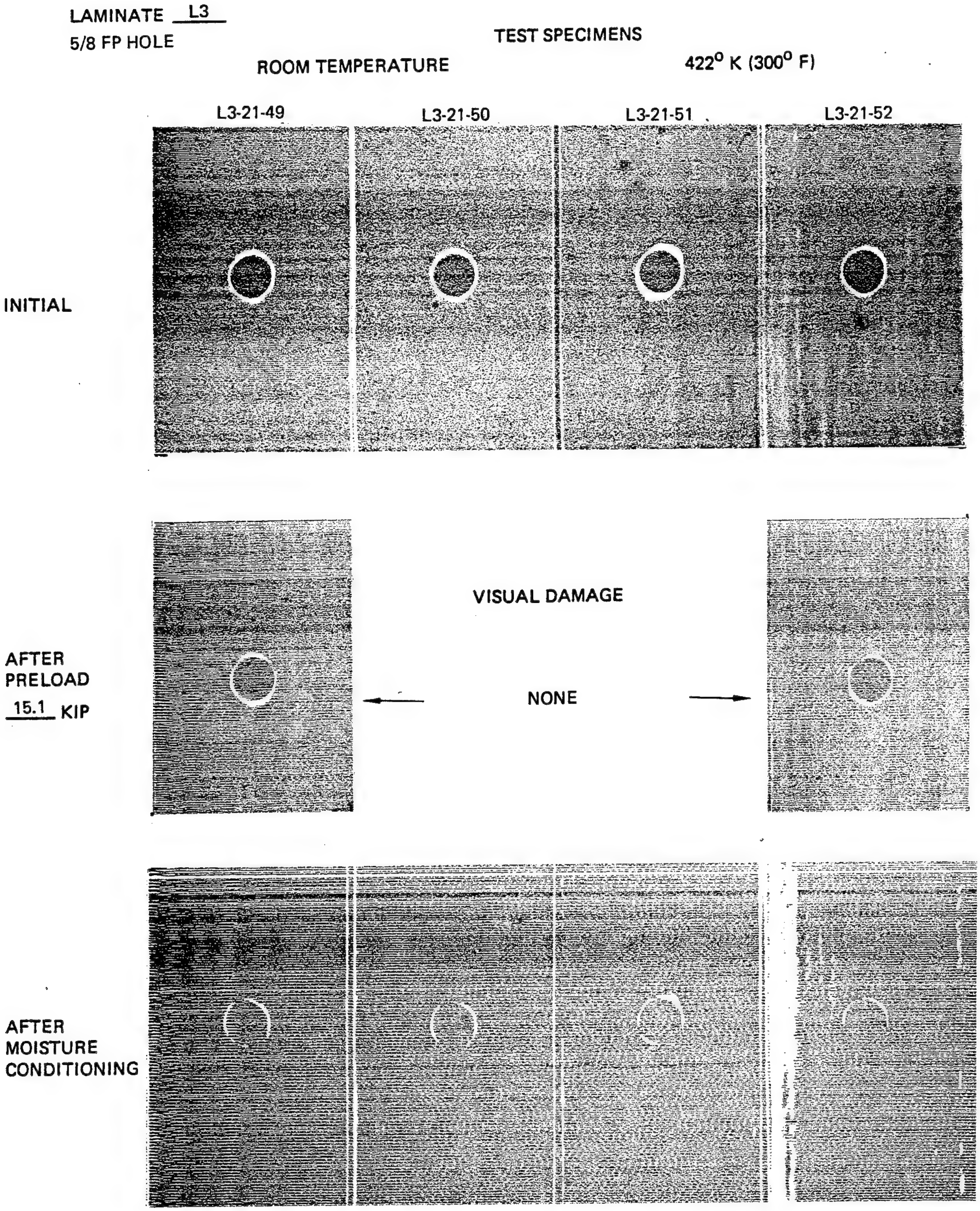


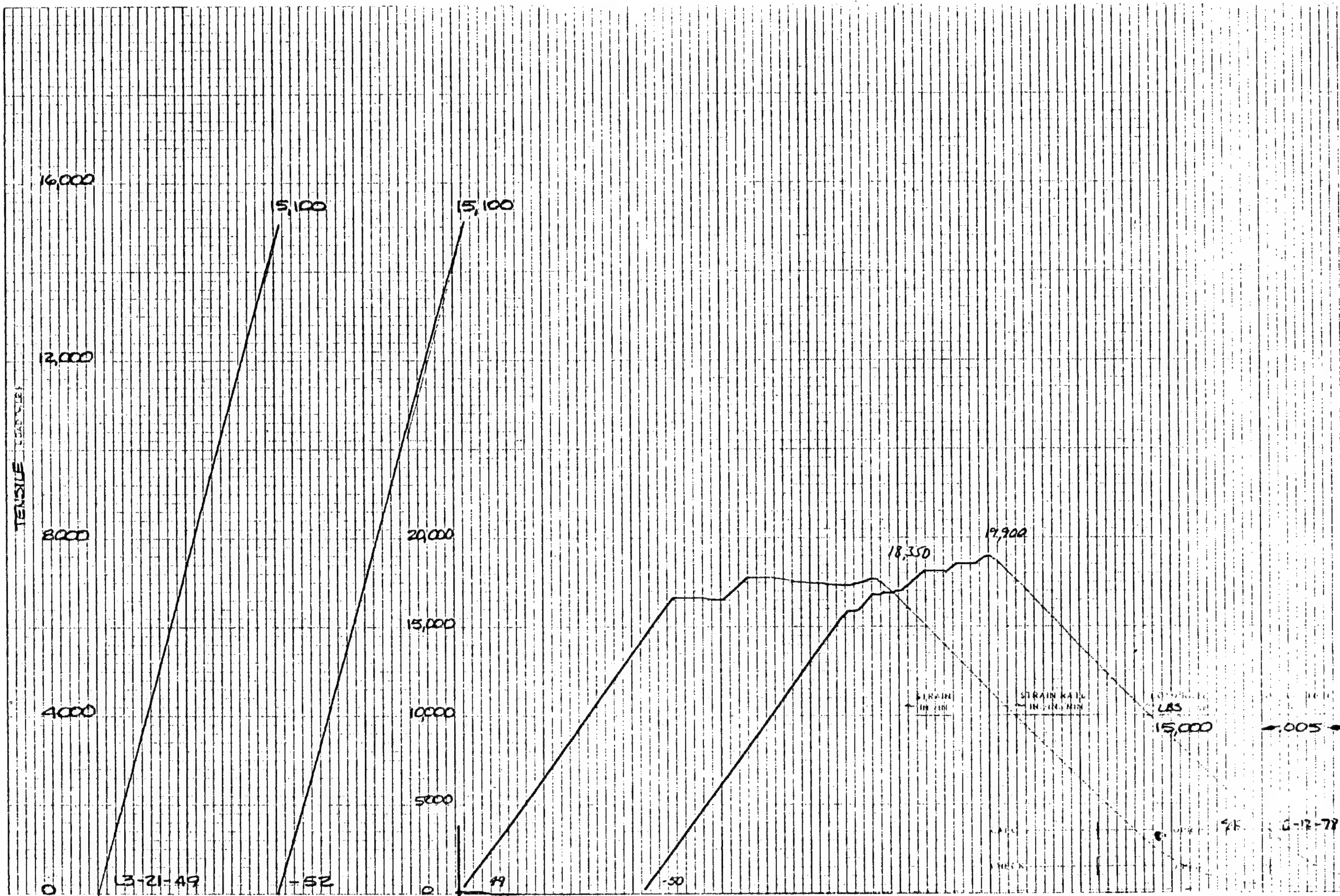
TENSILE
0
4000
8000
12,000
16,000
20,000
L3-21-45
-48
-45
-46
18,100
18,100
25,000
20,834
16,667
12,500
8333
4167
23,300
21,900
LBS
15,000
.002
.004
6-19-78

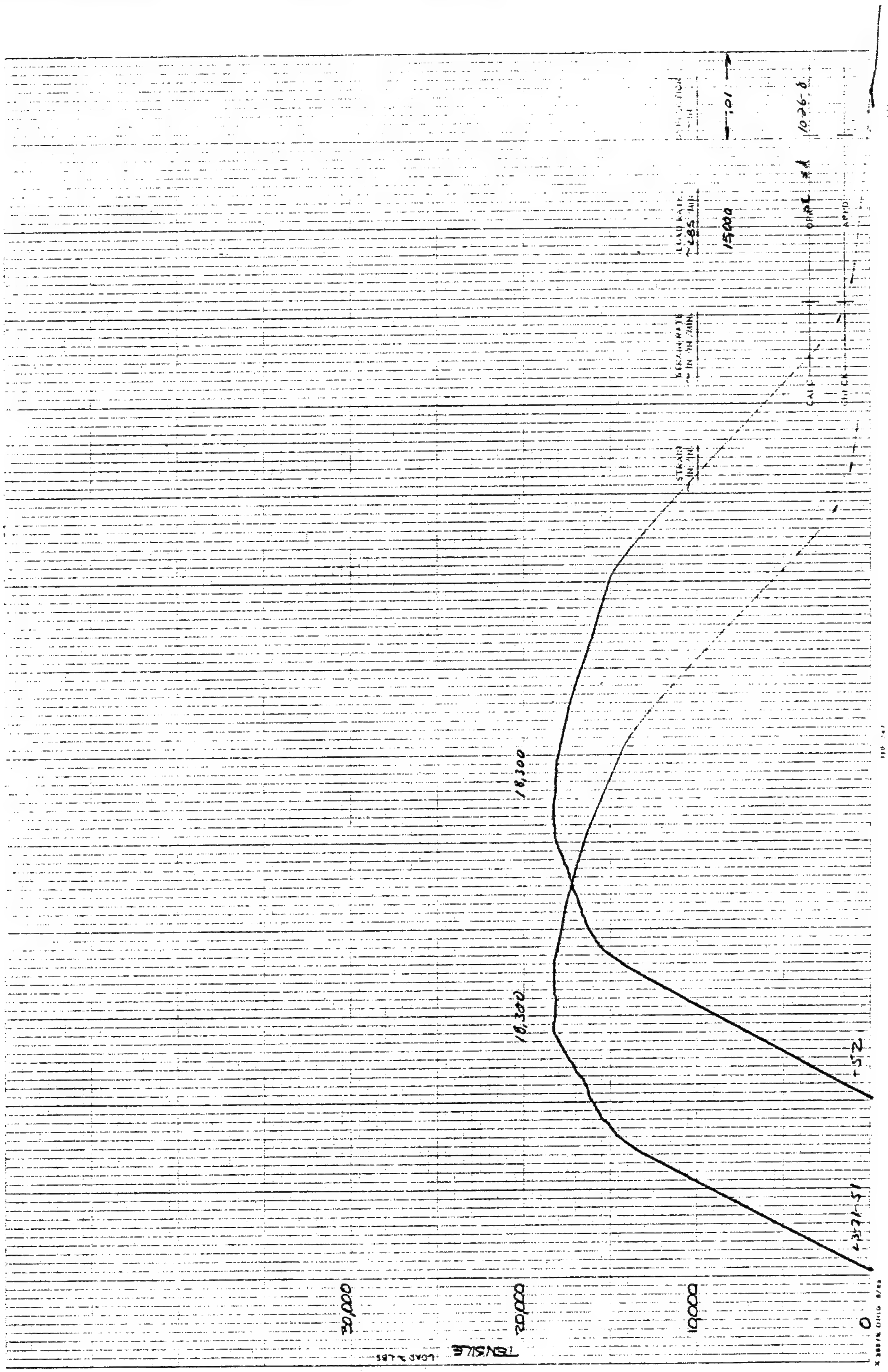


TENSILE LOAD ~ LBS
30,000
20,000
10,000
0
25,300
20,400
43-21-47
-48
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE ~ LBS/MIN.
15000
DEFLECTION ~ IN
.01
CALC
CHECK
ORIG
APPD
10-17-78

47 0703


LAMINATE L3
5/8 FP HOLE
TEST SPECIMENS
ROOM TEMPERATURE
422° K (300° F)
L3-21-49
L3-21-50
L3-21-51
L3-21-52
INITIAL
VISUAL DAMAGE
AFTER PRELOAD 15.1 KIP
NONE
AFTER MOISTURE CONDITIONING


TENSILE
16,000
12,000
8000
4000
0
L3-21-49
15,100
-52
15,100
20,000
15,000
10,000
5000
0
49
-50
18,350
19,900
STRAIN IN./IN.
STRAIN RATE IN./IN./MIN
LBS
15,000
.005
6-12-78


TENSILE
LOAD ~ LBS
30,000
20,000
10000
0
18,300
18,300
15000
1026-8
STRAIN IN/IN

LAMINATE L3

ALL GRAPHITE

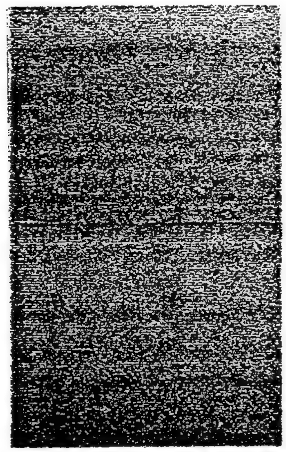
NO DEFECT

TEST SPECIMENS

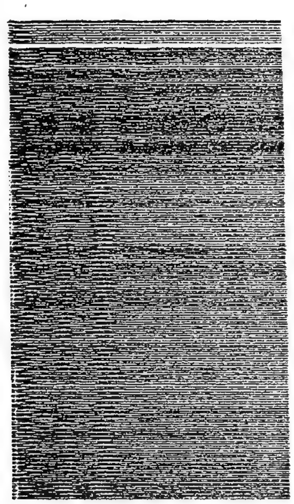
ROOM TEMPERATURE

L3-22-9

INITIAL



AFTER
MOISTURE
CONDITIONING



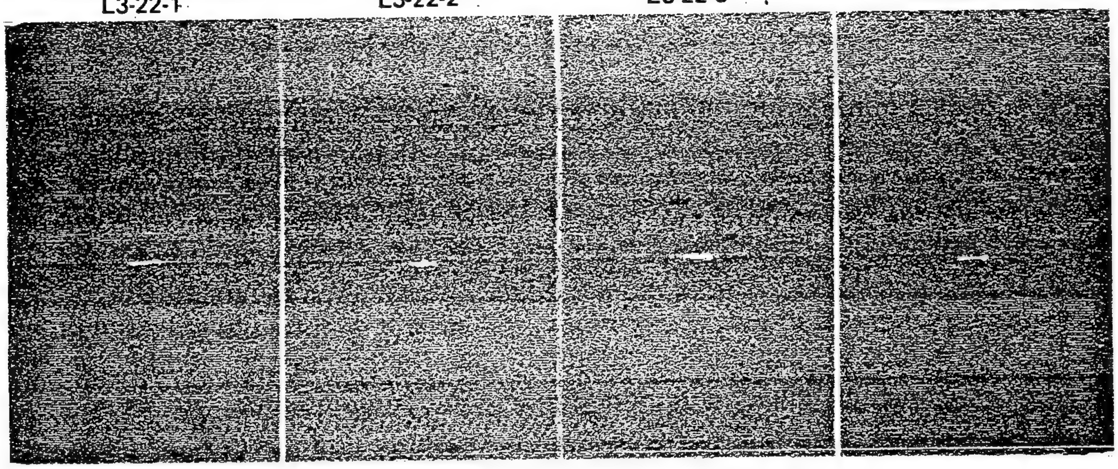
LAMINATE L3
5/8 HP SLIT
ALL GRAPHITE

TEST SPECIMENS

ROOM TEMPERATURE | 422° K (300° F)

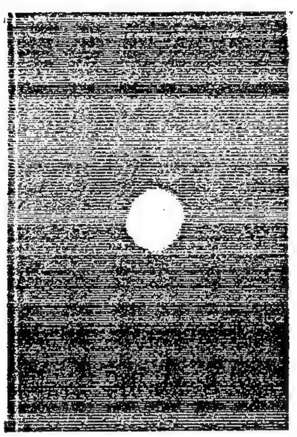
L3-22-1 | L3-22-2 | L3-22-3 | L3-22-4

INITIAL

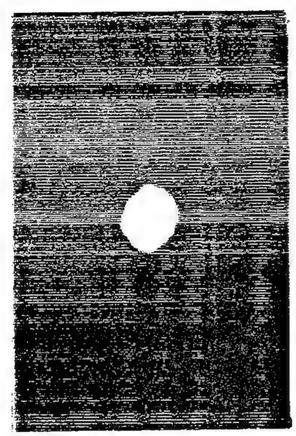


VISUAL DAMAGE

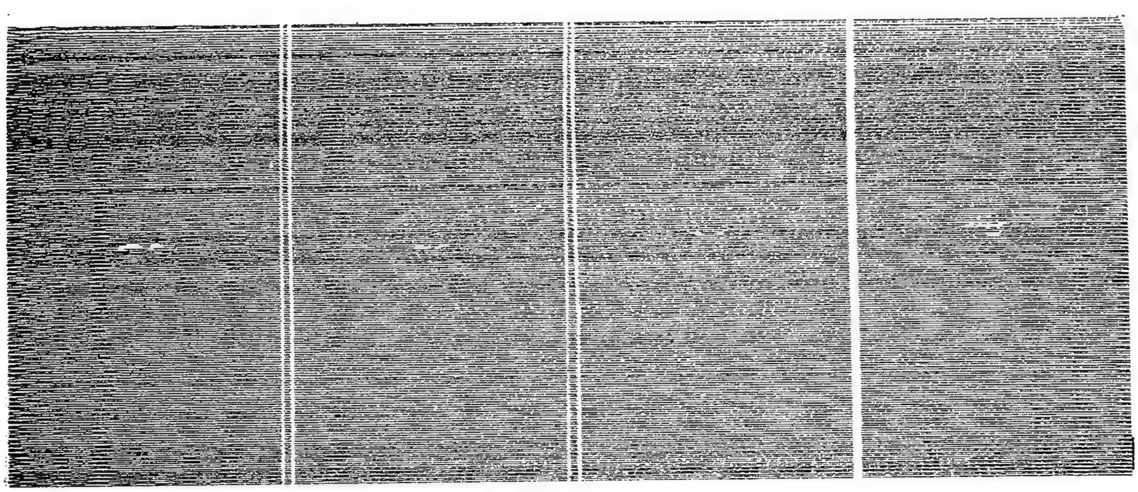
AFTER
PRELOAD
21.7 KIP

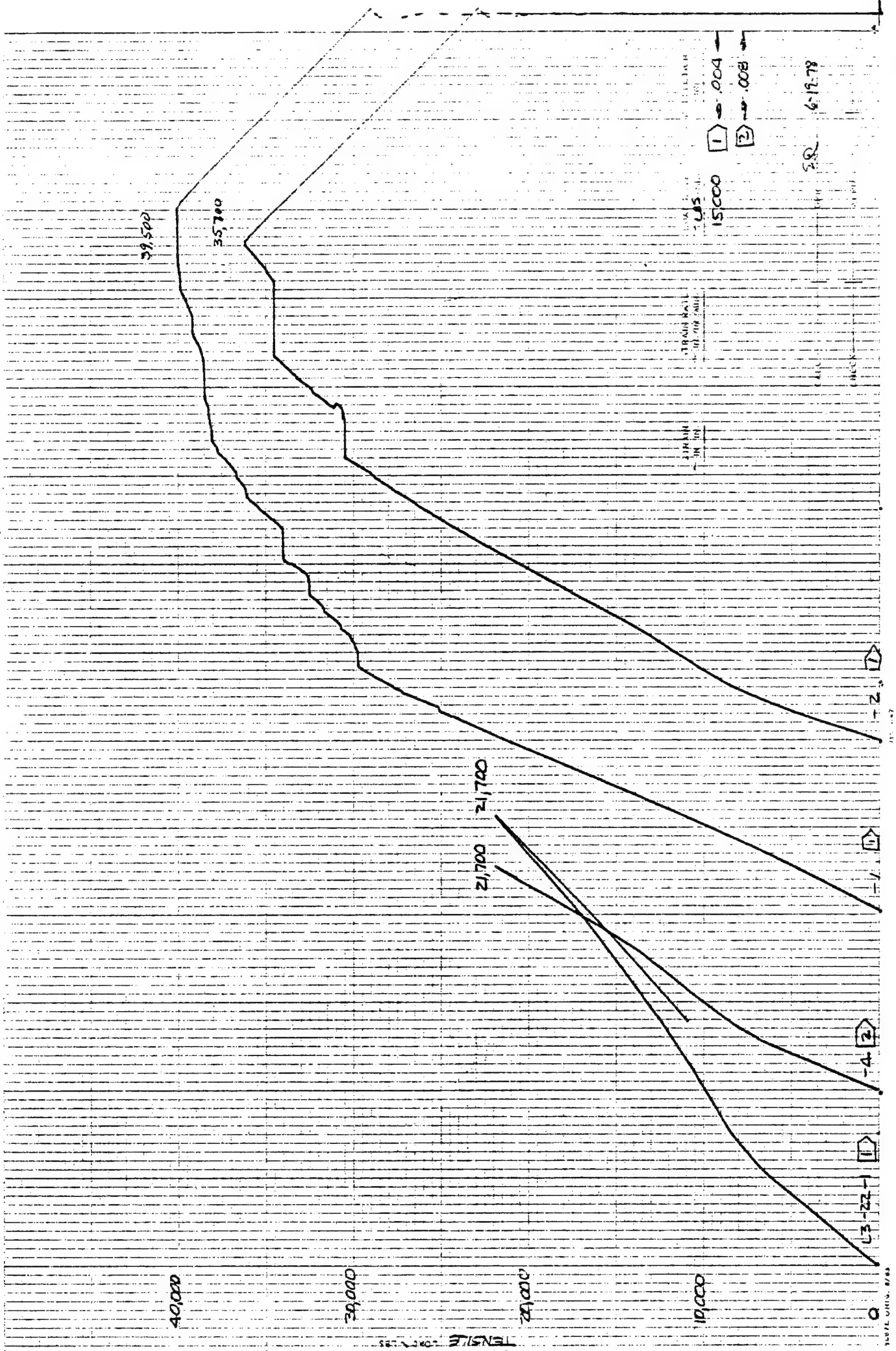


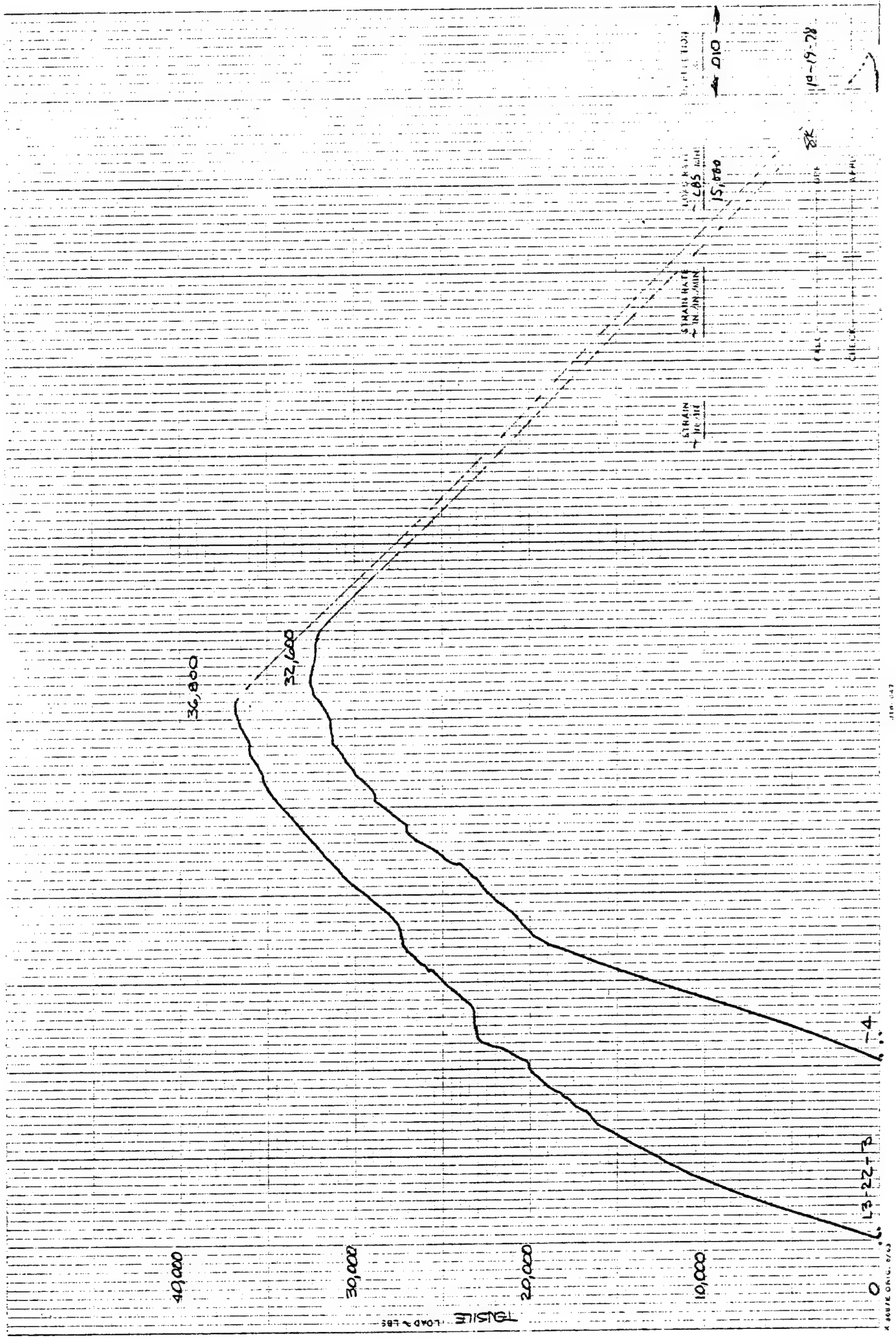
NONE



AFTER
MOISTURE
CONDITIONING




TENSILE
40,000
30,000
20,000
10,000
0
39,500
35,700
21,700
21,700
L3-22-1
-4
-2
-1
15000
.004
.008
6-19-78


36,800
32,600
L3-22-T-3
-4
40,000
30,000
20,000
10,000
0
TENSILE
LOAD ~ LBS
D10
10-19-78

LAMINATE L3

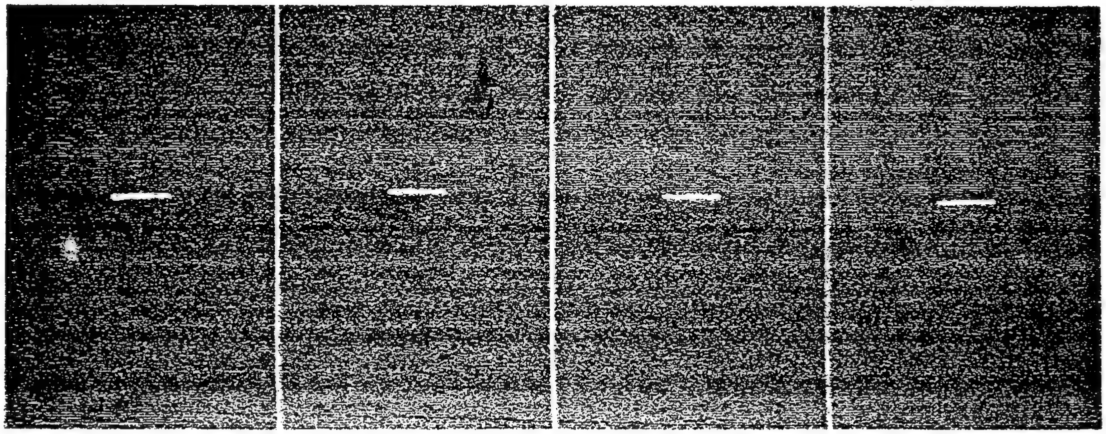
5/8 HP SLIT

ALL GRAPHITE

TEST SPECIMENS

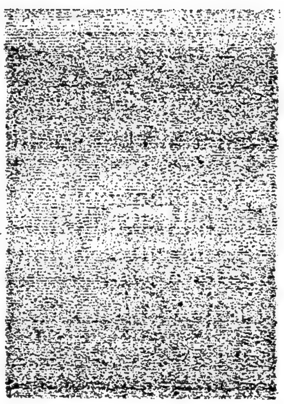
ROOM TEMPERATURE		422° K (300° F)	
L3-22-5	L3-22-6	L3-22-7	L3-22-8

INITIAL



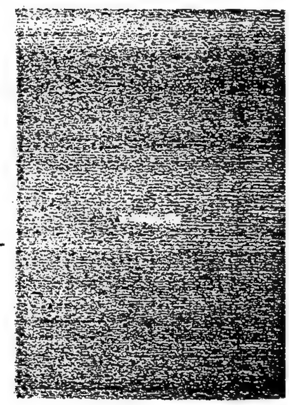
AFTER PRELOAD

12.2 KIP

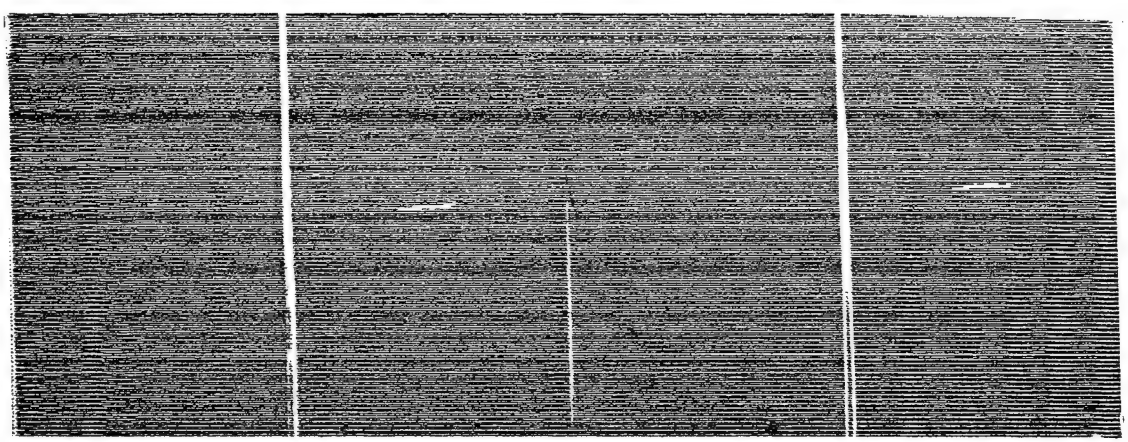


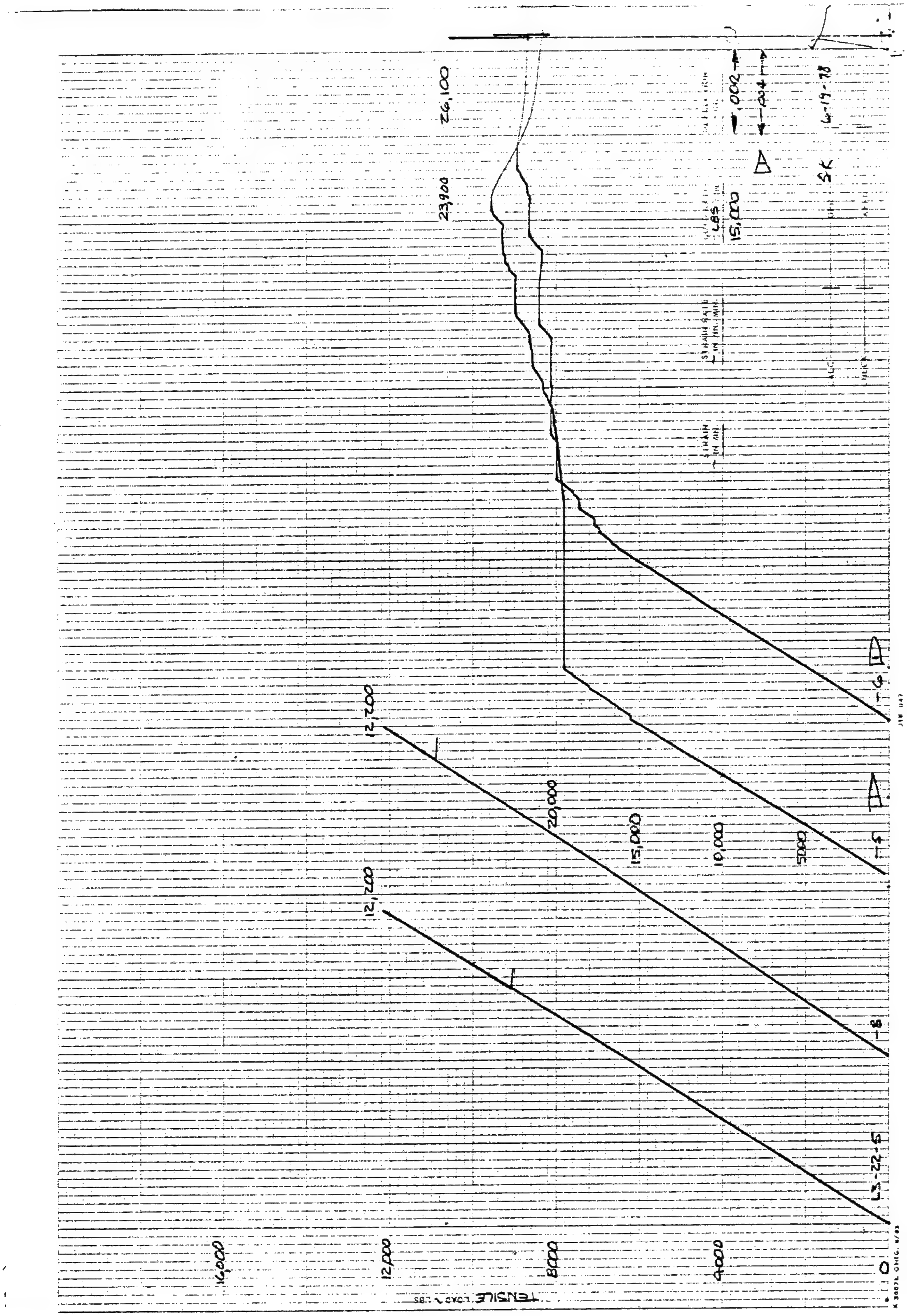
VISUAL DAMAGE

NONE

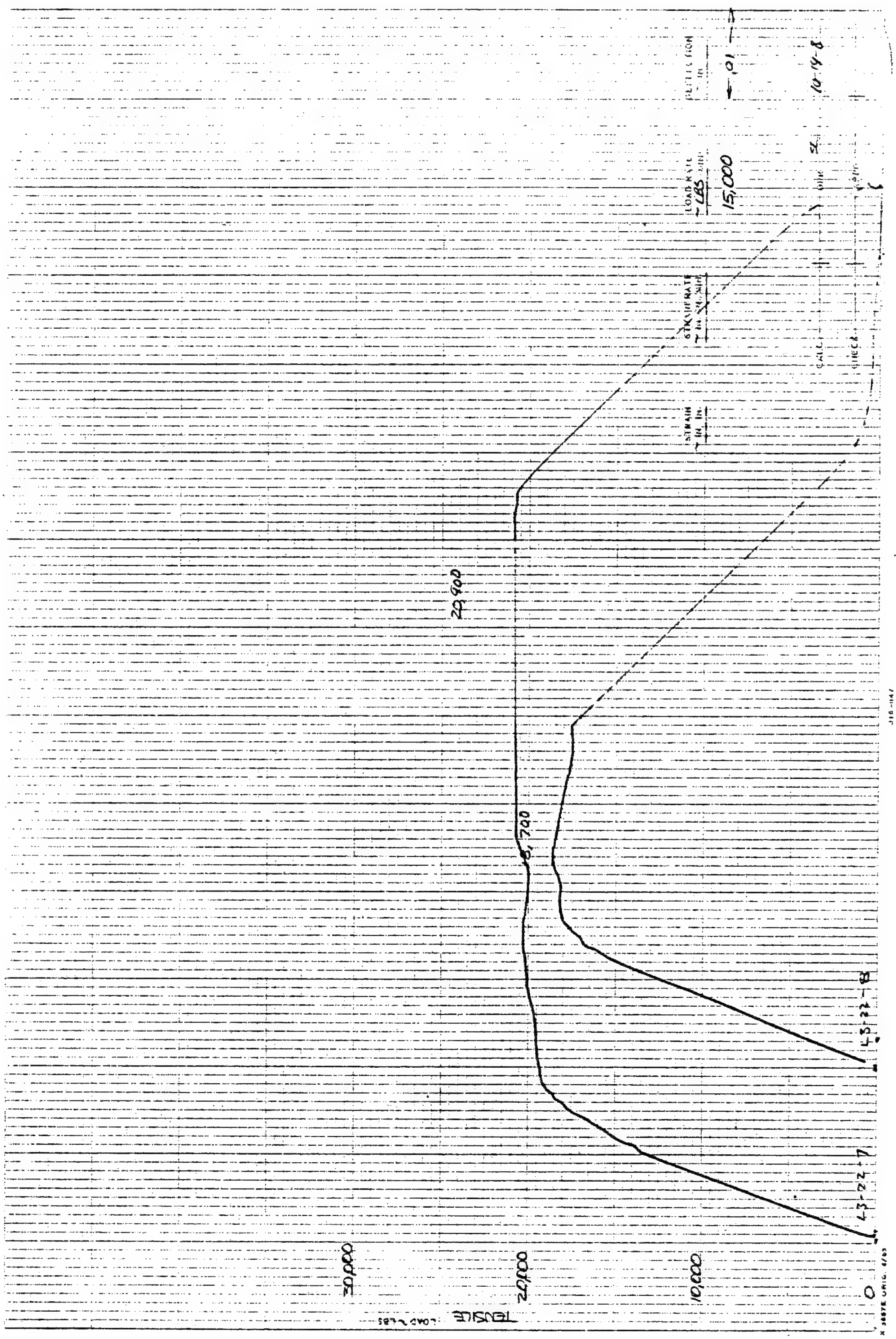


AFTER MOISTURE CONDITIONING





TENSILE LOAD LBS
16,000
12,000
8000
4000
0
L3-22-5
-8
-4
-6
12,200
12,200
20,000
15,000
10,000
5000
23,900
26,100
LBS
15,000
.002
.004
6-19-78
SK

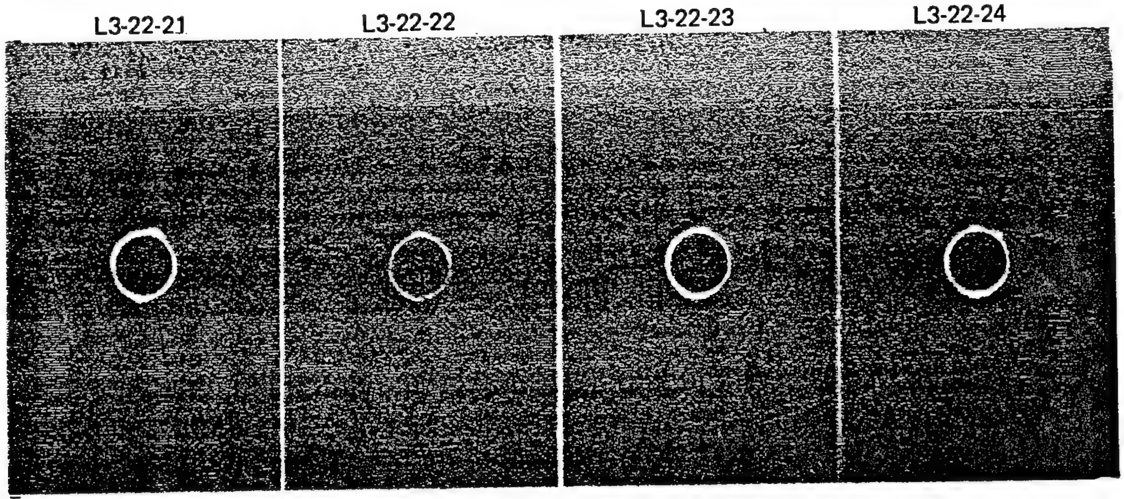

TENSILE
LOAD ~ LBS
30,000
20,000
10,000
0
43-22-7
43-22-8
20,900
15,000
10-14-8
.01

LAMINATE L3
5/8 FP SLIT
ALL GRAPHITE

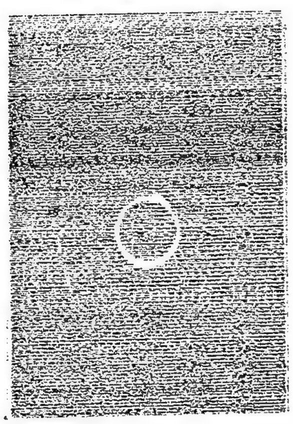
TEST SPECIMENS

ROOM TEMPERATURE		422° K (300° F)	
L3-22-21	L3-22-22	L3-22-23	L3-22-24

INITIAL

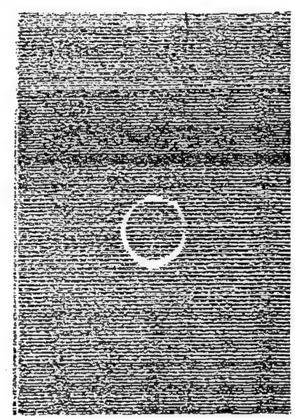


AFTER PRELOAD
12.2 KIP

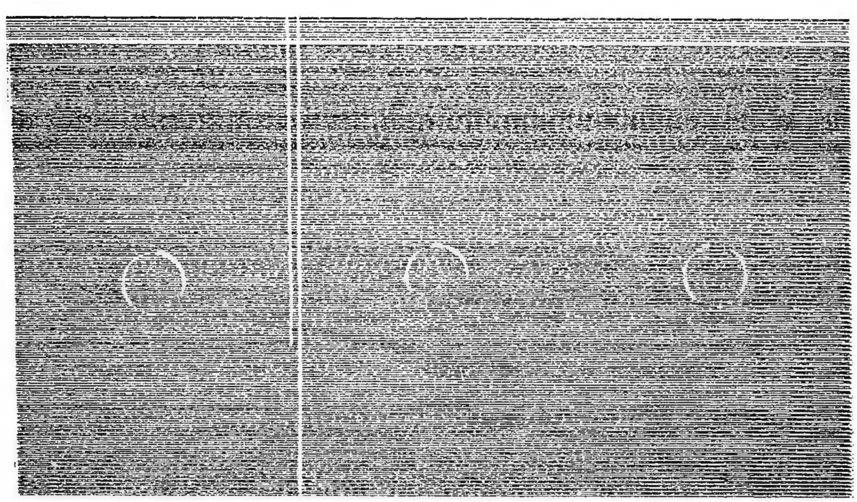


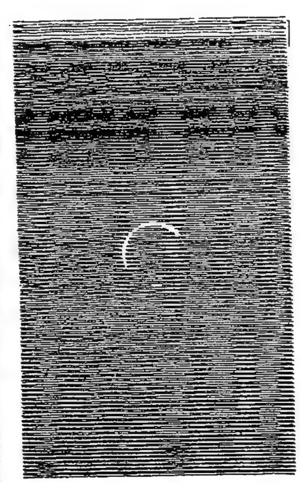
VISUAL DAMAGE

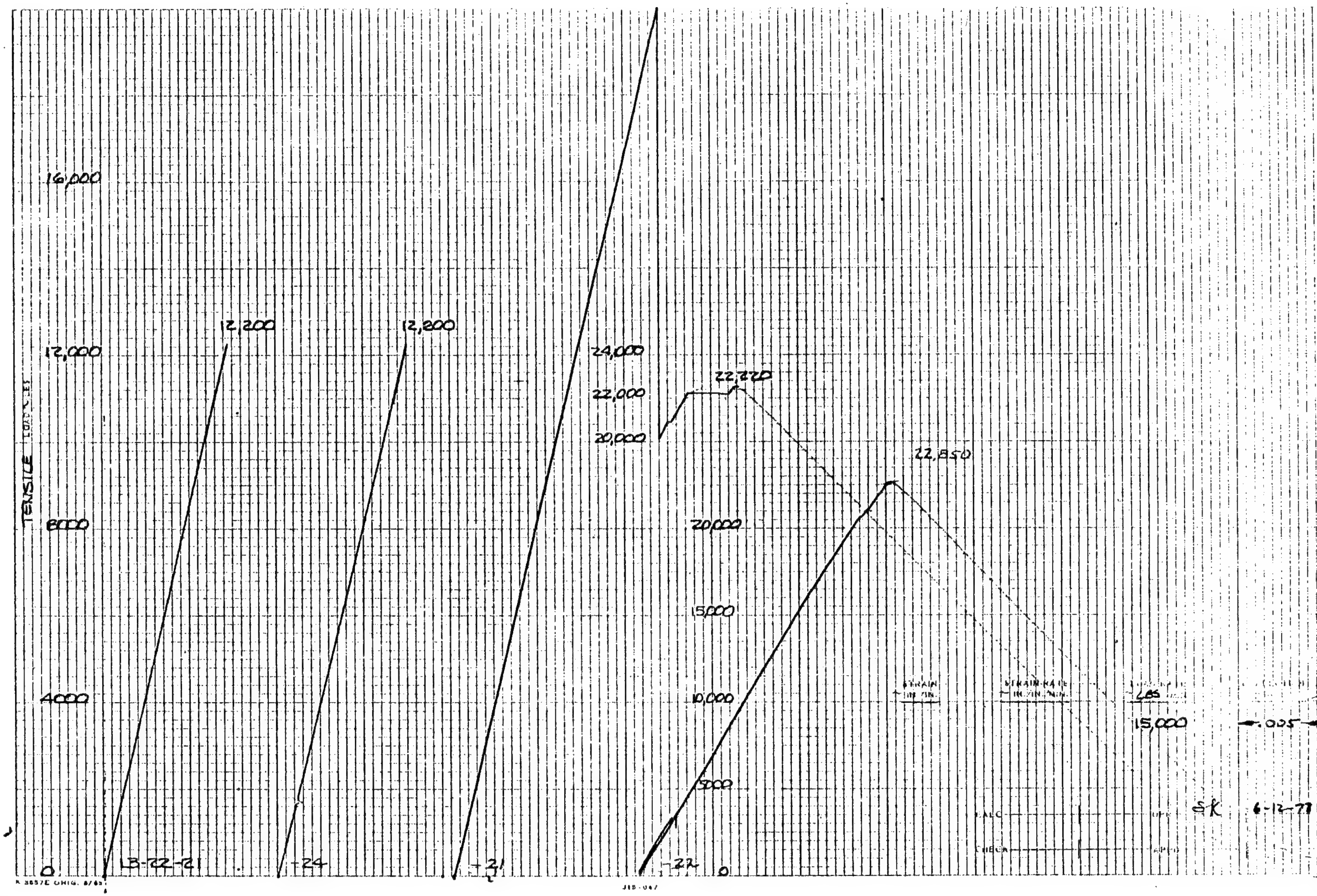
← NONE →



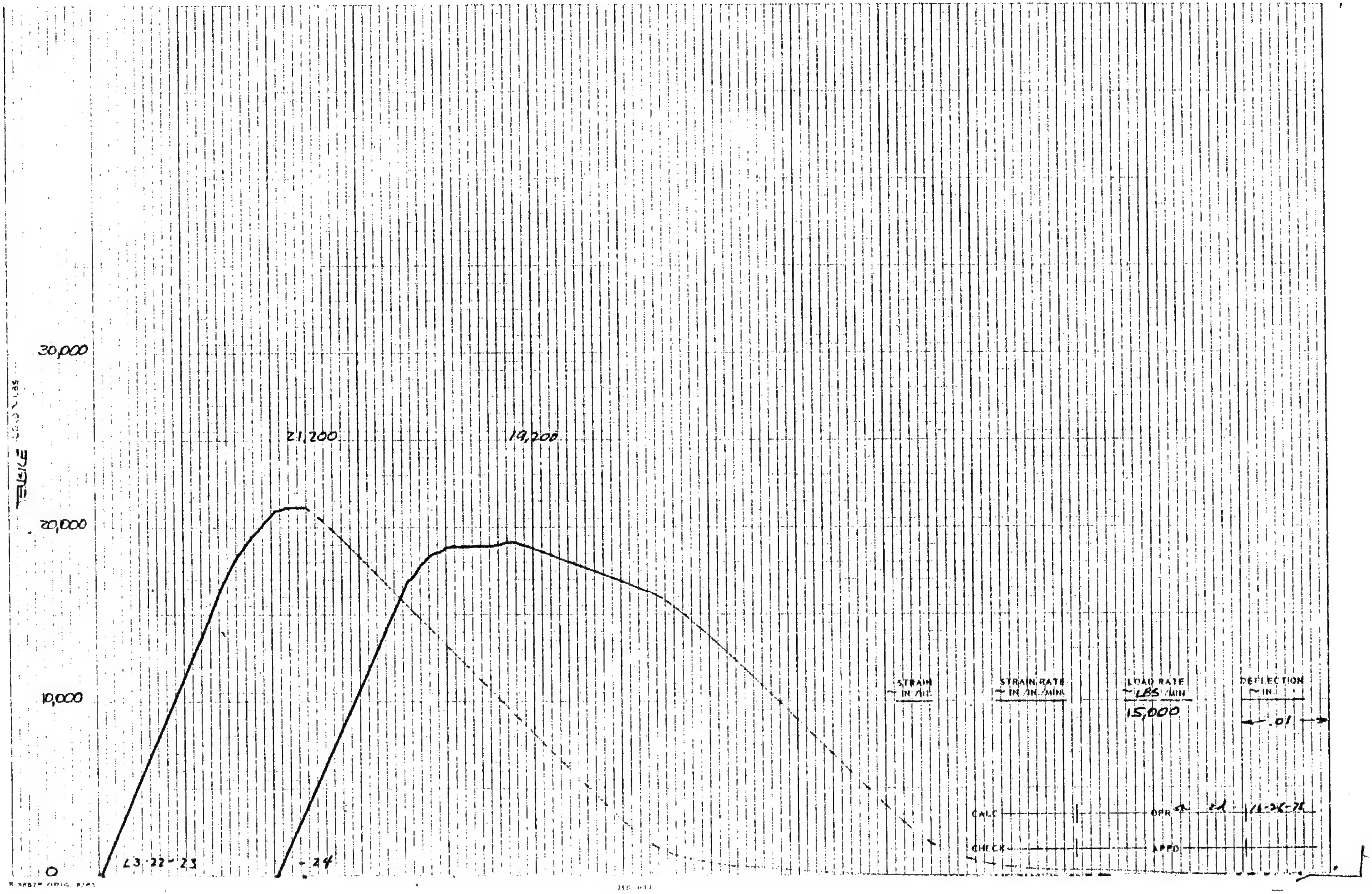
AFTER MOISTURE CONDITIONING







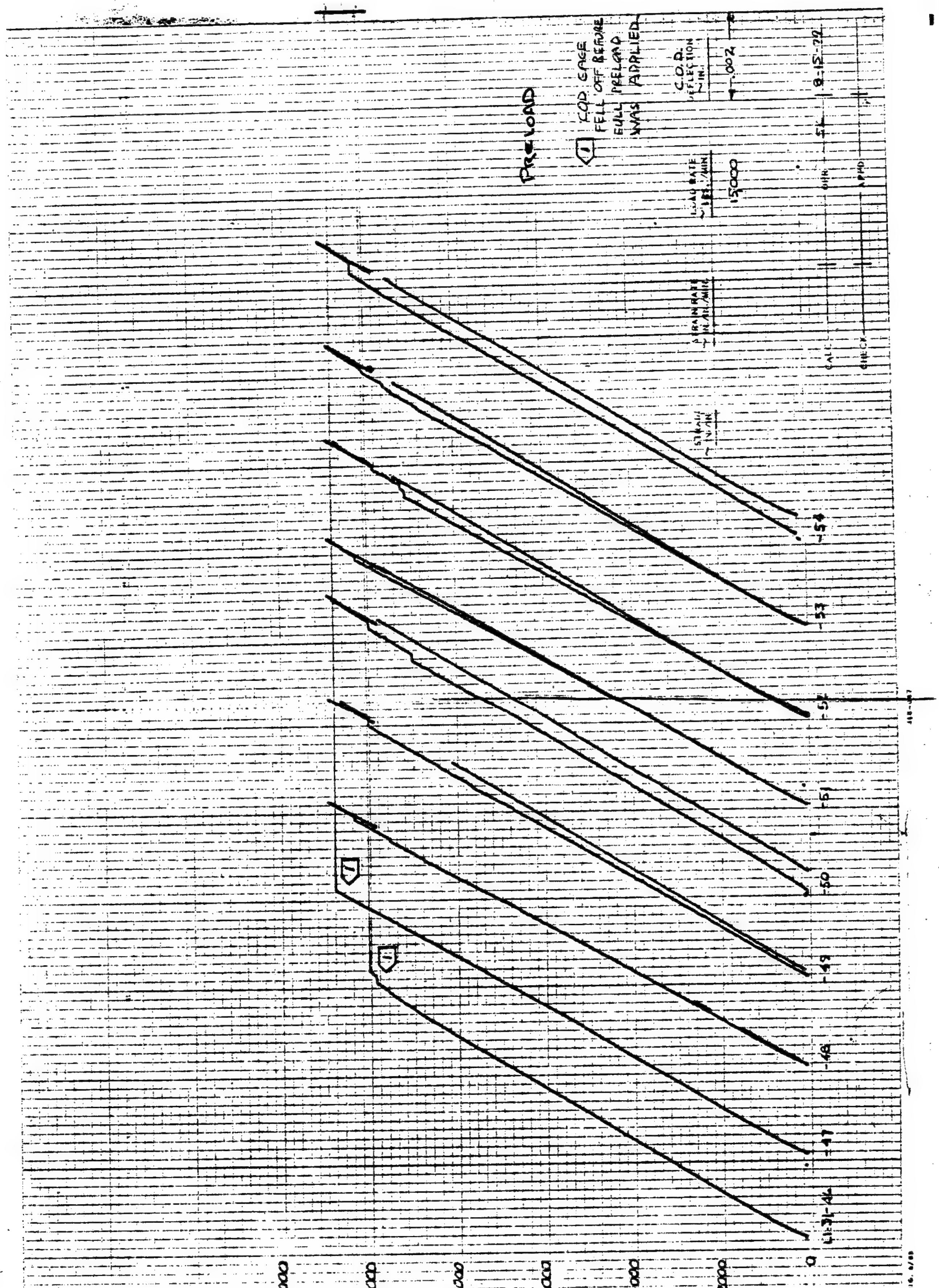
TENSILE
16,000
12,000
8000
4000
0
12,200
12,200
24,000
22,000
20,000
22,220
22,850
20,000
15,000
10,000
5000
0
13-22-21
-24
-21
-22
LBS
15,000
.005
SK 6-12-77

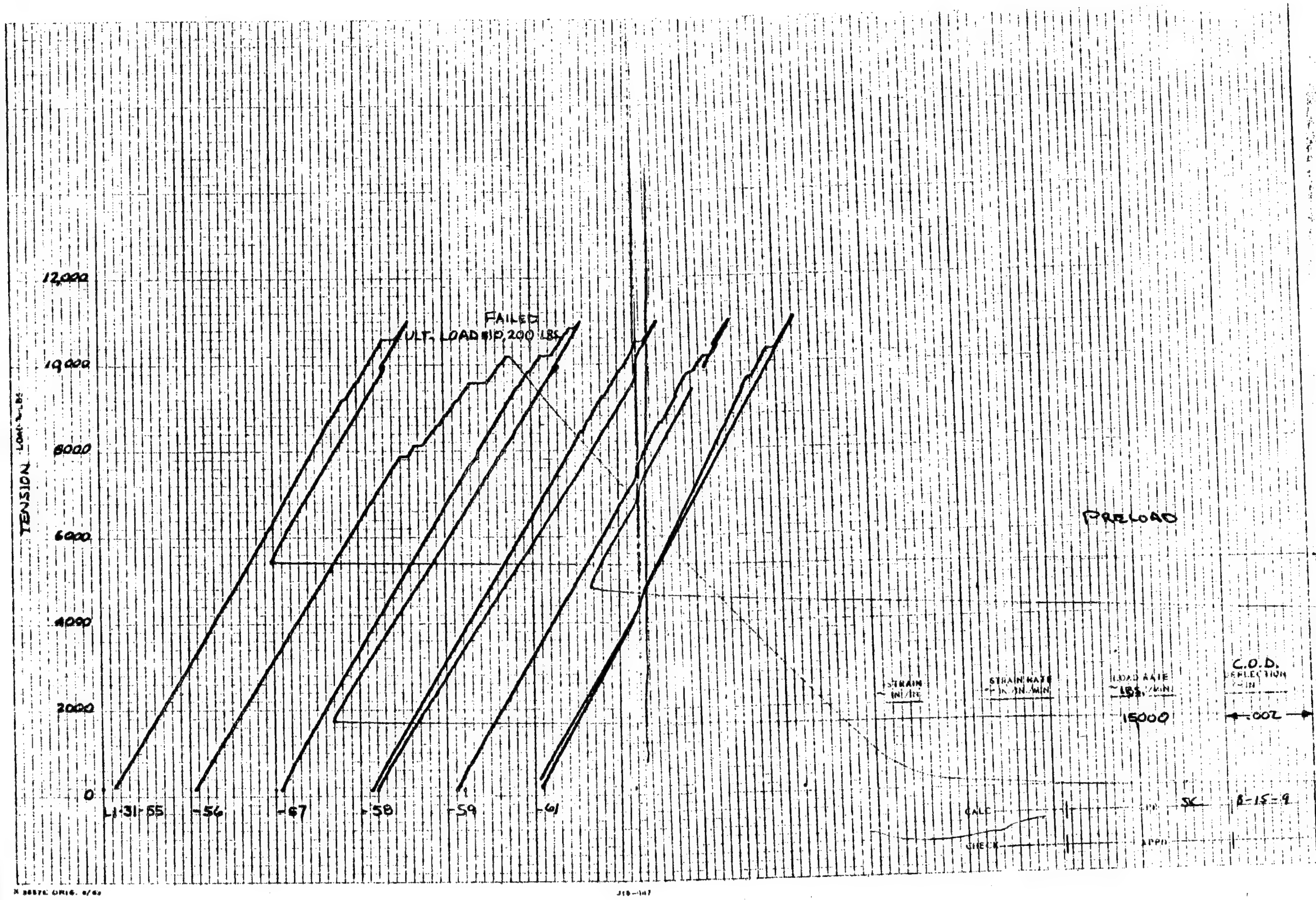

30,000
20,000
10,000
0
21,200
19,200
23-22-23
-24
STRAIN ~ IN /IN
STRAIN RATE ~ IN /IN /MIN
LOAD RATE ~ LBS /MIN
15,000
DEFLECTION ~ IN
.01
CALC
CHECK
OPR
APPD
11-26-78

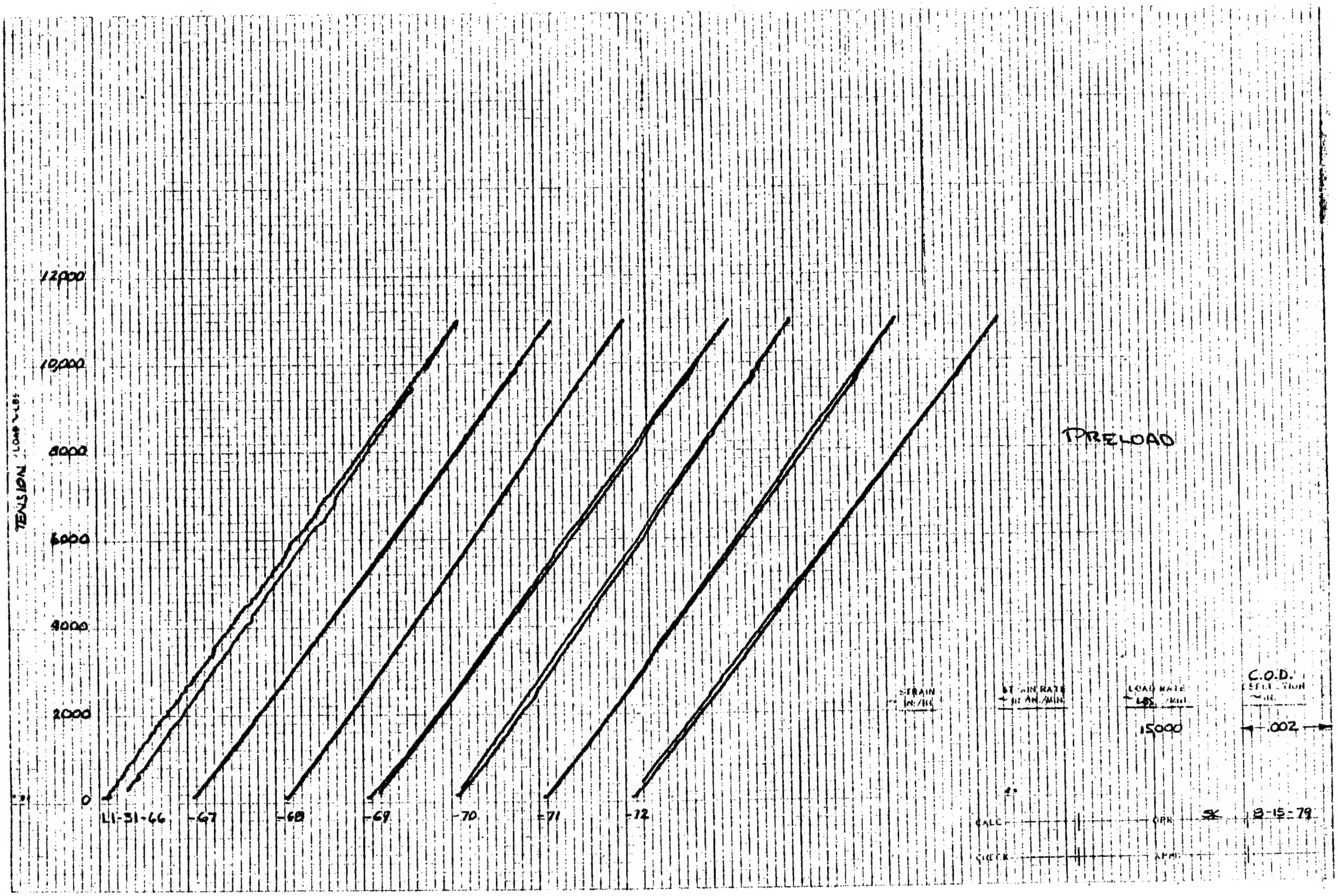
APPENDIX D

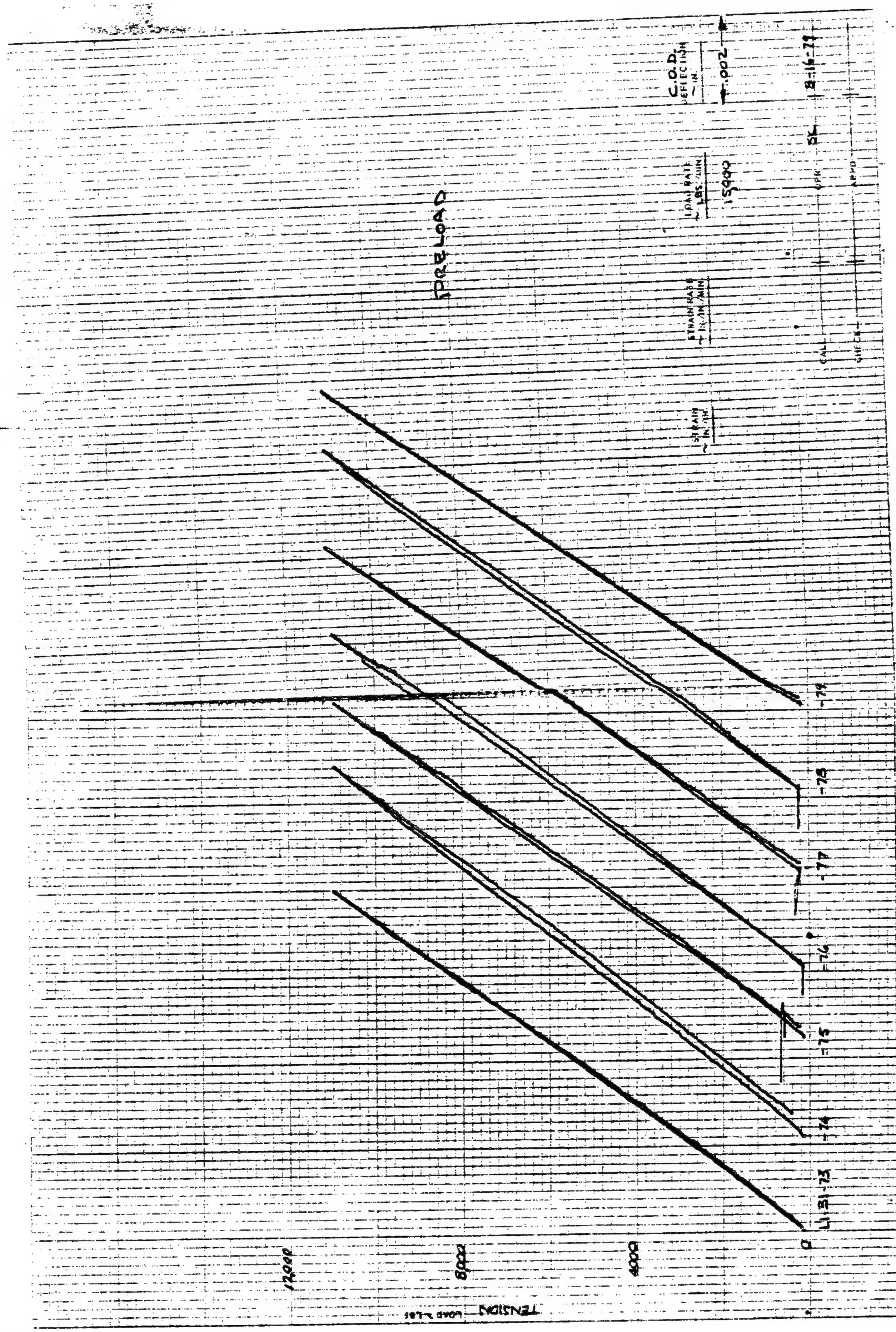
CYCLIC TEST DAMAGE GROWTH DATA

This appendix contains the ultrasonic C-scan examinations and the crack opening displacement COD records made of the cyclic test specimens. The ultrasonic examinations were made several times during the course of the testing, giving a progressive record of the damage development in these specimens.


PRELOAD
1 COD GAGE FELL OFF BEFORE FULL PRELOAD WAS APPLIED
C.O.D. DEFLECTION ~IN.
.002
LOAD RATE ~LBS/MIN
15,000
STRAIN RATE ~IN/IN/MIN
8-15-72
TENSION LOAD ~LBS
0
2000
4000
6000
8000
10,000
12,000
L1-31-46
-47
-48
-49
-50
-51
-52
-53
-54

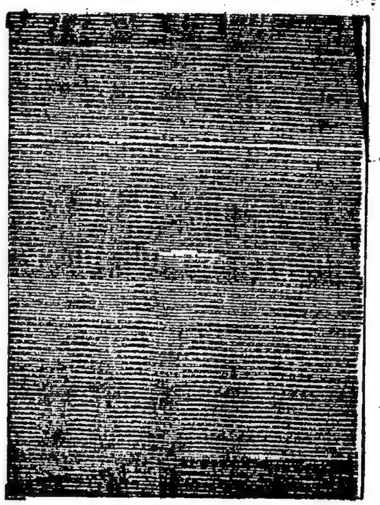

TENSION LOAD-LBS
12,000
10,000
8000
6000
4000
2000
0
FAILED
ULT. LOAD #10,200 LBS
PRELOAD
L1-31-55
-56
-67
-58
-59
-61
STRAIN IN/IN
STRAIN RATE IN/IN/MIN
LOAD RATE LBS/MIN
15000
C.O.D. DEFLECTION IN
.002
CALC
CHECK
APPD
SK
8-15-9


PRELOAD
TENSION, LOAD ~ LBS
12,000
10,000
8000
6000
4000
2000
0
L1-31-66
-67
-68
-69
-70
-71
-72
STRAIN IN/IN
STRAIN RATE IN/IN/MIN
LOAD RATE LBS/MIN
15000
C.O.D.
.002
CALC
CHECK
OPR
APPR
SK
8-15-79



PRELOAD
C.O.D. DEFLECTION ~IN.
.002
LOAD RATE ~LBS/MIN
15900
STRAIN RATE ~IN/IN/MIN
STRAIN ~IN/IN
OPR
SK
CALL
CHECK
APPD
8-16-79
TENSION LOAD ~LBS
12000
8000
4000
0
LI-31-73
-74
-75
-76
-77
-78
-79

ULTRASONIC C-SCAN DATA

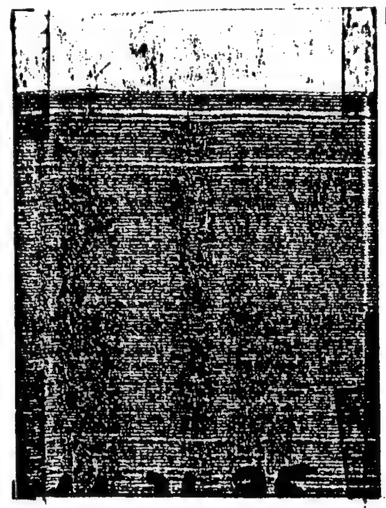


BEFORE TEST

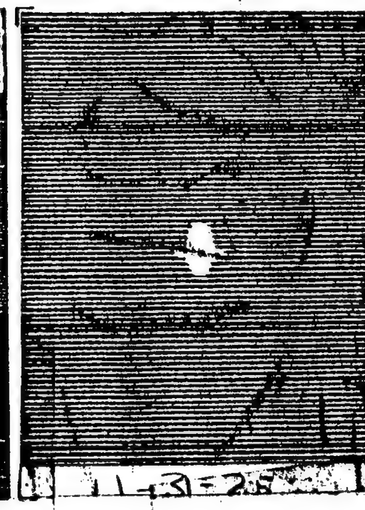
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING



10 CYCLES

10^3 CYCLES

CYCLIC LOAD 46700 (10.500)

R RATIO 0.05

TEST TEMPERATURE Room

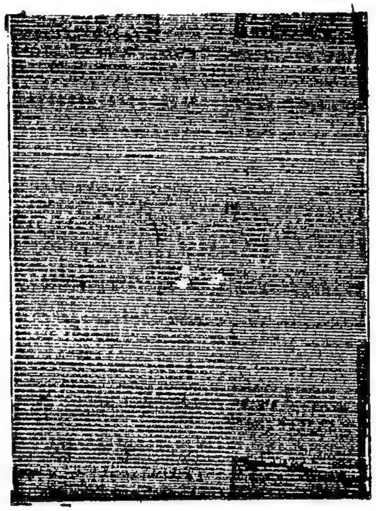
LAMINATE L1

SPECIMEN NO. L1-31-25

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

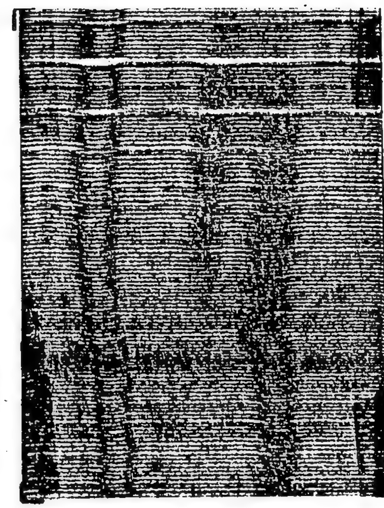


BEFORE TEST

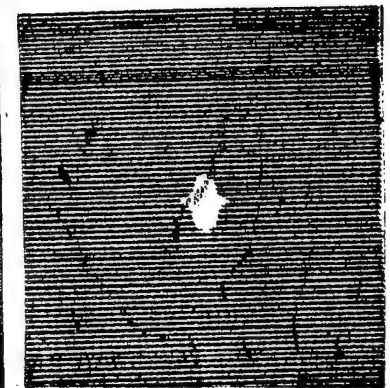
NO PRELOAD

AFTER PRELOAD

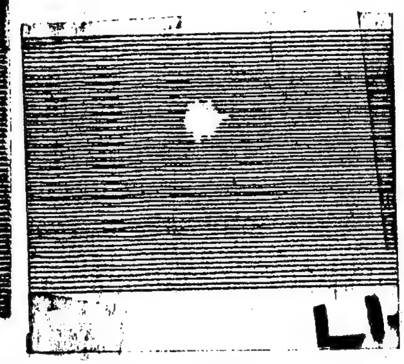
MAXIMUM LOAD –



AFTER MOISTURE CONDITIONING



100 CYCLES



10^6 CYCLES

CYCLIC LOAD 46700 (10500)

R RATIO 0.05

TEST TEMPERATURE Room

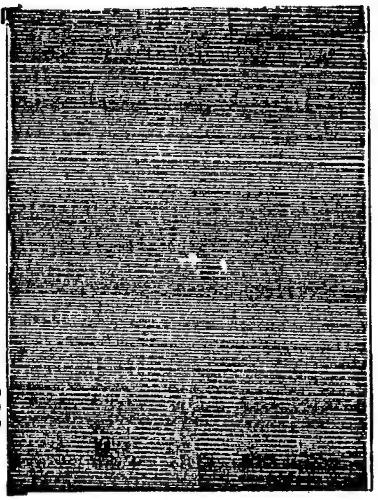
LAMINATE L1-

SPECIMEN NO. L1-31-26

DEFECT 3/8 FP SLIT

TEST TYPE CYCLIC

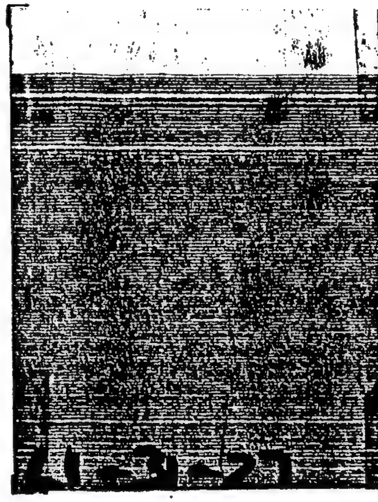
ULTRASONIC C-SCAN DATA



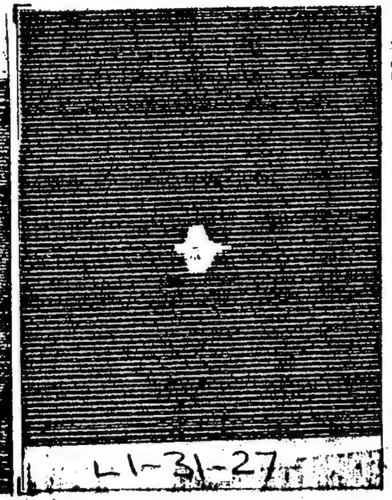
BEFORE TEST

NO PRE LOAD

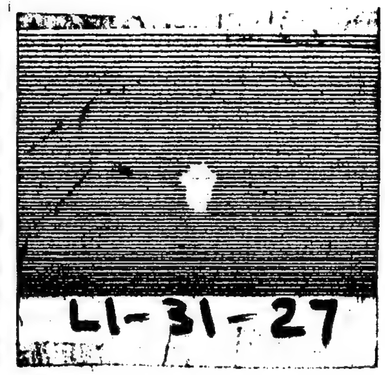
AFTER PRELOAD



AFTER MOISTURE CONDITIONING



100 CYCLES



10^7 CYCLES

MAXIMUM LOAD ______

CYCLIC LOAD 46700 (10500)

R RATIO 0.05

TEST TEMPERATURE ROOM

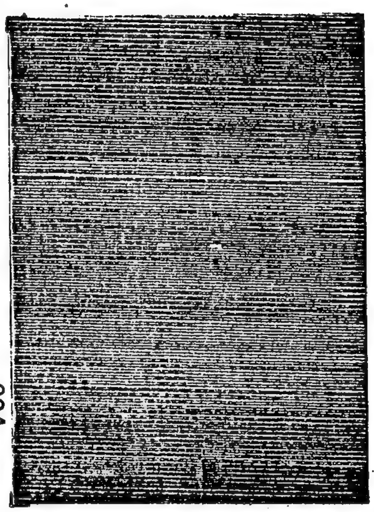
LAMINATE L1

SPECIMEN NO. L1-31-27

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

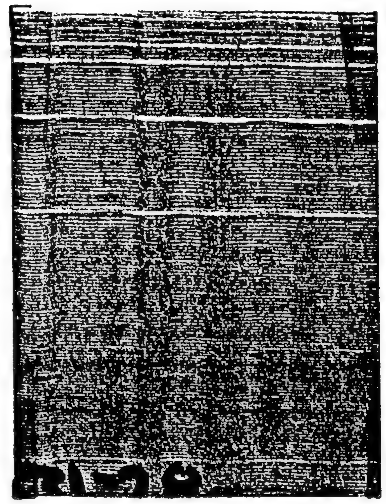


BEFORE TEST

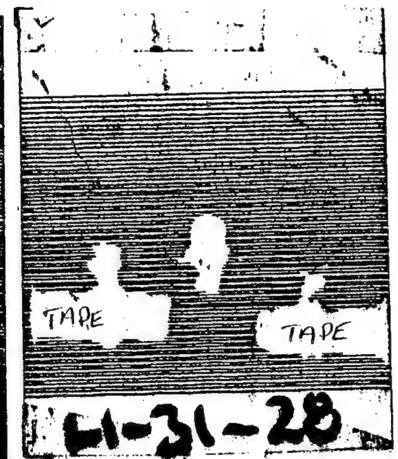
NO PRELOAD

AFTER PRELOAD

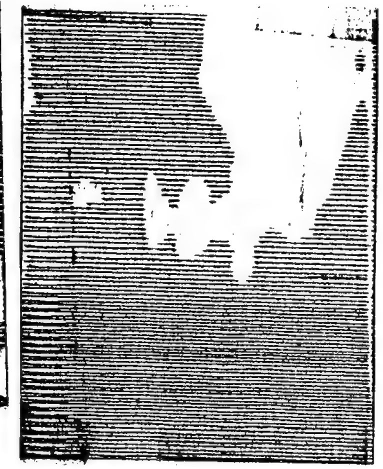
MAXIMUM LOAD –



AFTER MOISTURE CONDITIONING



10 CYCLES



10^3 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-28

DEFECT 5/8 FP SLIT

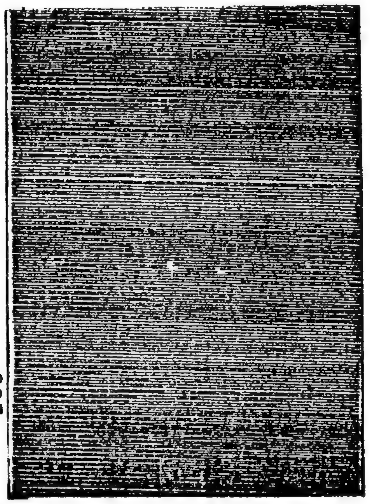
TEST TYPE CYCLIC

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO .05

TEST TEMPERATURE 422 K (300°F)

ULTRASONIC C-SCAN DATA

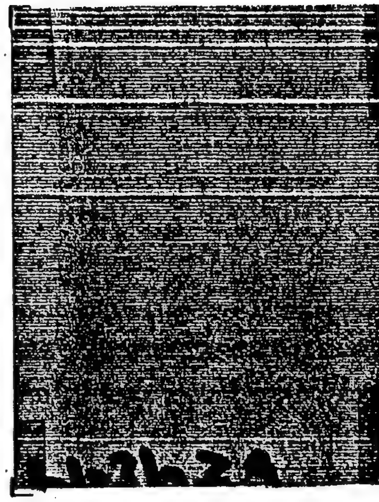


BEFORE TEST

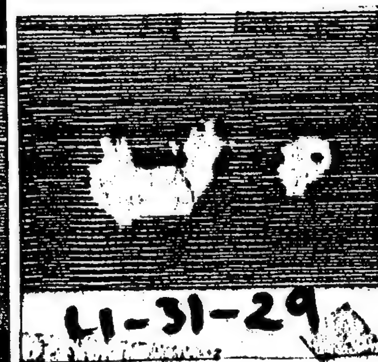
NO PRELOAD

AFTER PRELOAD

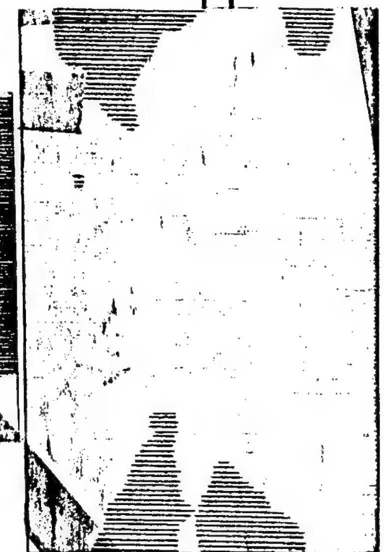
MAXIMUM LOAD -



AFTER MOISTURE CONDITIONING



100 CYCLES



10^6 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

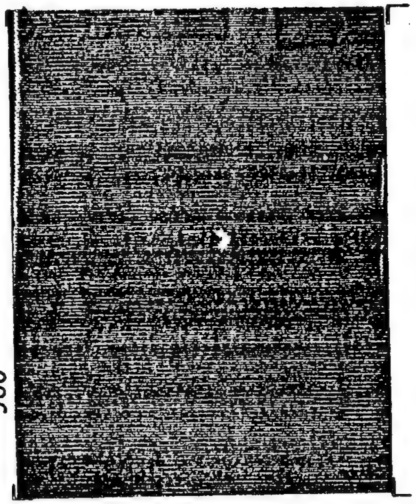
LAMINATE L1

SPECIMEN NO. L1-31-29

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

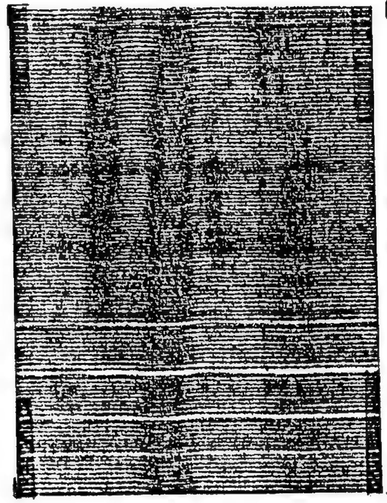


BEFORE TEST

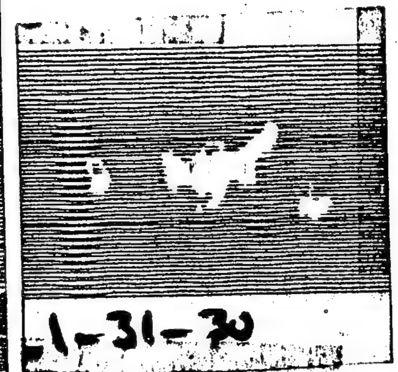
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD ______



AFTER MOISTURE CONDITIONING



100 CYCLES

______ CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-30

DEFECT 5/8 FP SLIT

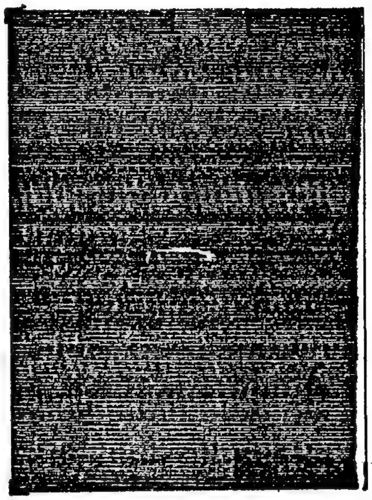
TEST TYPE CYCLIC

CYCLIC LOAD 46.7 kN (10.5 KIP)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

ULTRASONIC C-SCAN DATA

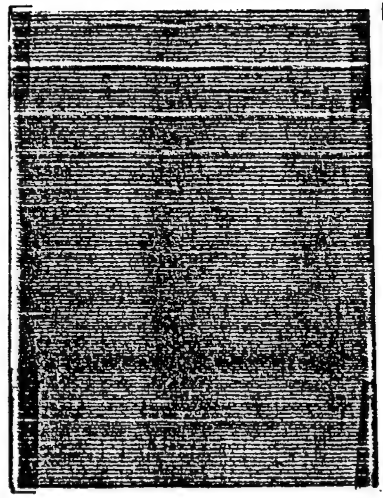


BEFORE TEST

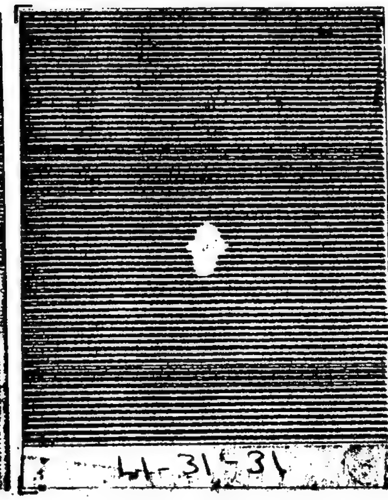
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD –



AFTER MOISTURE CONDITIONING

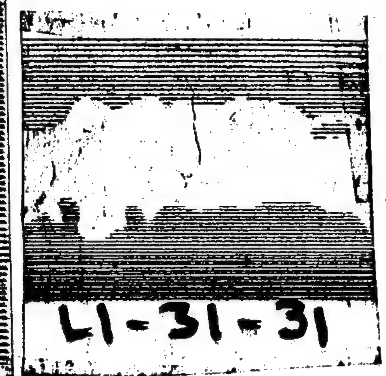


10 CYCLES

CYCLIC LOAD 40 kN (9 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM



750 CYCLES (FAILURE)

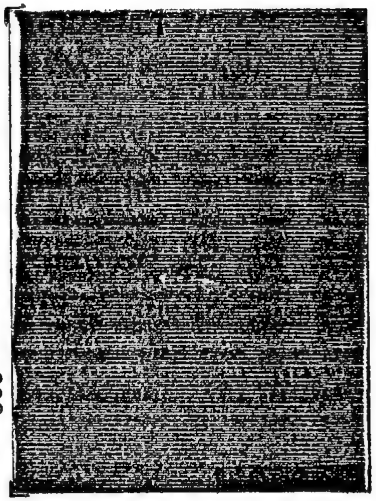
LAMINATE L1

SPECIMEN NO. L1-31-31

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

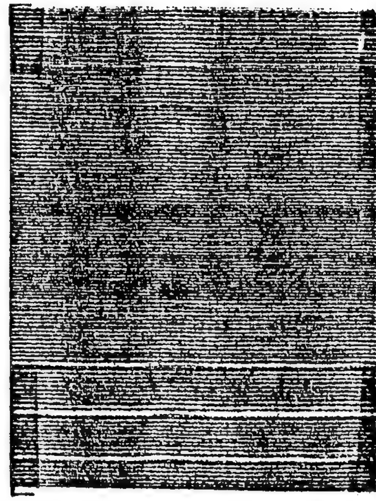


BEFORE TEST

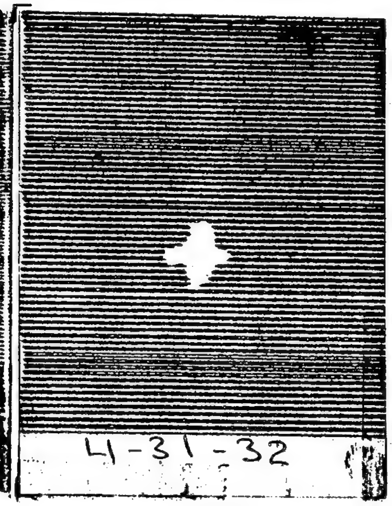
NO PRELOAD

AFTER PRELOAD

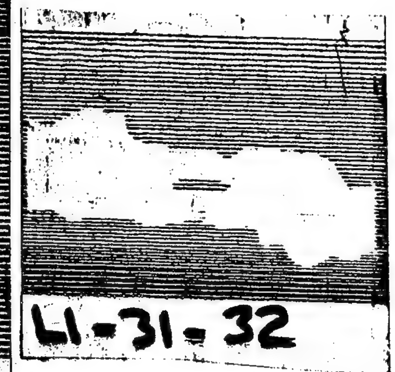
MAXIMUM LOAD ___



AFTER MOISTURE CONDITIONING



100 CYCLES



650 CYCLES
(FAILURE)

LAMINATE L1

SPECIMEN NO. L1-31-32

DEFECT 5/8 FP SLIT

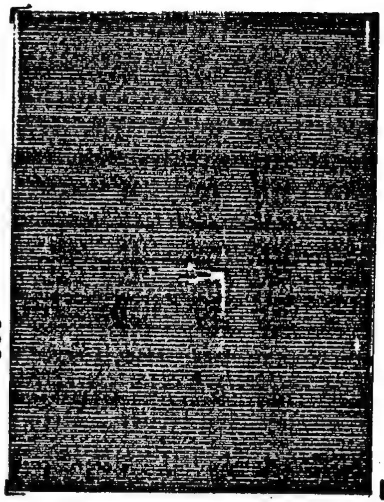
TEST TYPE CYCLIC

CYCLIC LOAD 40 kN (9.0 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM

ULTRASONIC C-SCAN DATA

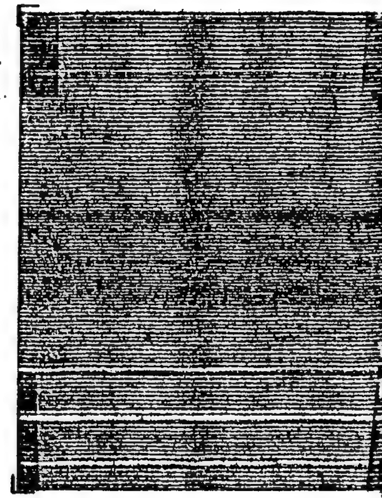


BEFORE TEST

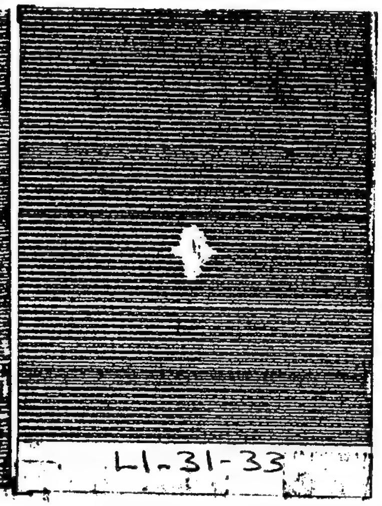
NO PRELOAD

AFTER PRELOAD

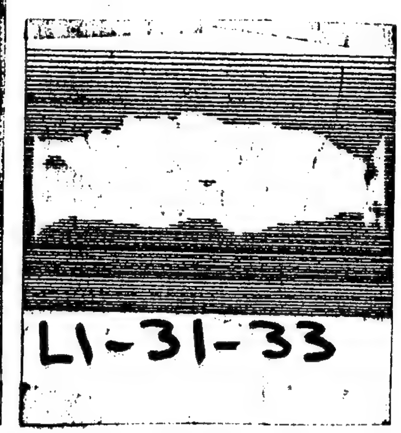
MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING



100 CYCLES



2800 CYCLES
(FAILURE)

CYCLIC LOAD 37.8 kN (8.5 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM

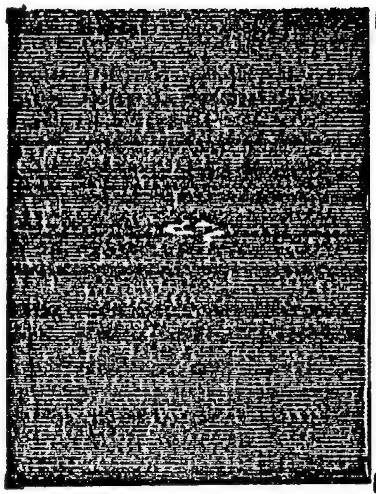
LAMINATE L1

SPECIMEN NO. L1-31-33

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

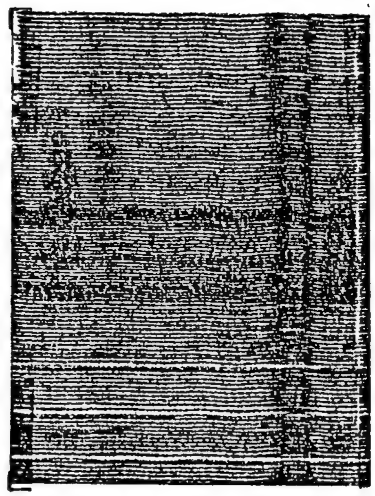


BEFORE TEST

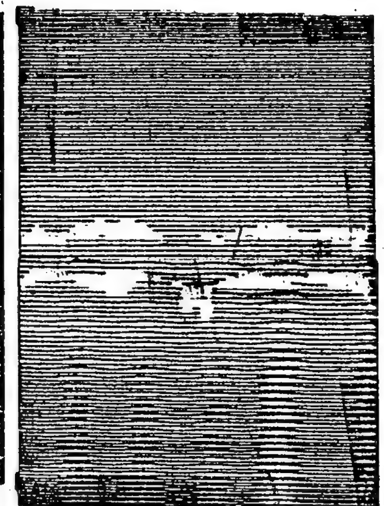
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING



2 CYCLES
(FAILURE)

CYCLIC LOAD 26.7 kN (6.0 kip)

R RATIO -1.0

TEST TEMPERATURE 422 k (300°F)

____ CYCLES

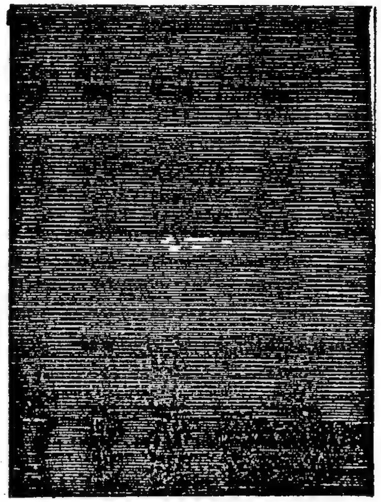
LAMINATE L1

SPECIMEN NO. L1-31-34

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

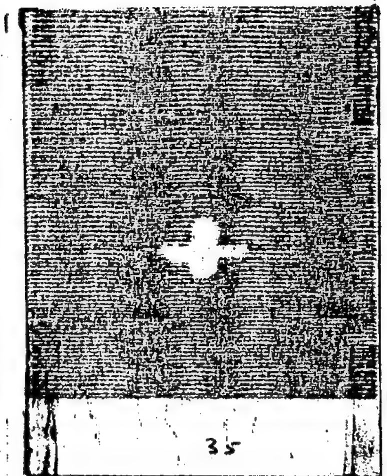
NO PRELOAD

AFTER PRELOAD

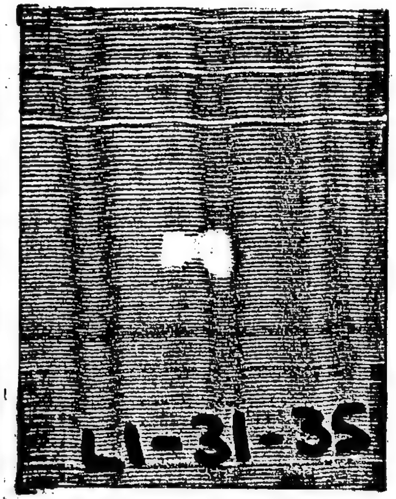
MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



10 CYCLES



10^6 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-35

DEFECT 5/8 FP SLIT

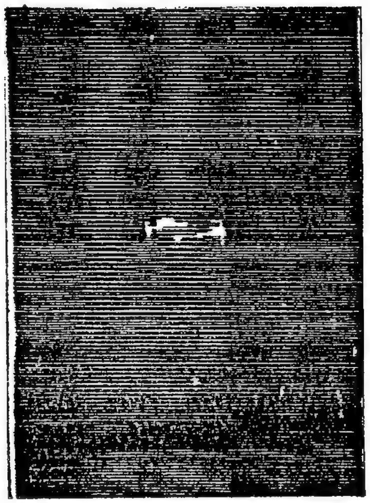
TEST TYPE CYCLIC

CYCLIC LOAD 46.7 kN (10.5 KIP)

R RATIO 0.05

TEST TEMPERATURE ROOM

ULTRASONIC C-SCAN DATA



BEFORE TEST

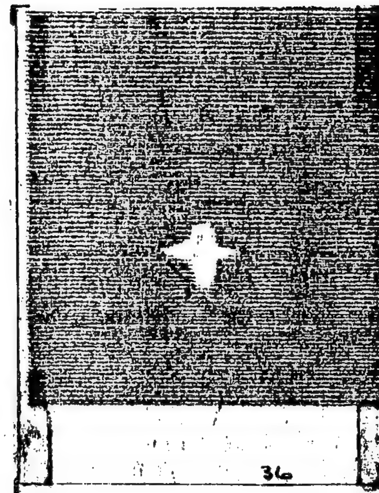
NO PRELOAD

AFTER PRELOAD

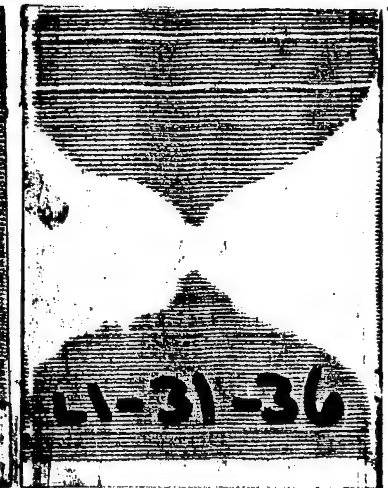
MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES



10^7 CYCLES
COMPRESSION OVERLOAD

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE ROOM

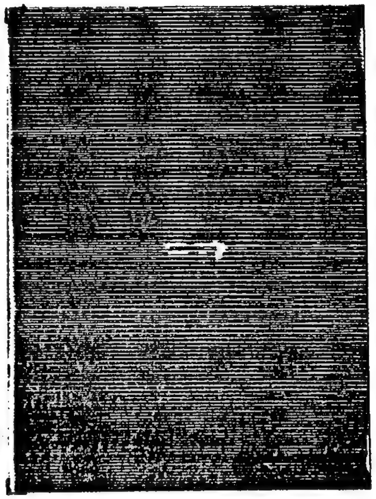
LAMINATE L1

SPECIMEN NO. L1-31-36

DEFECT 5/8 FD SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

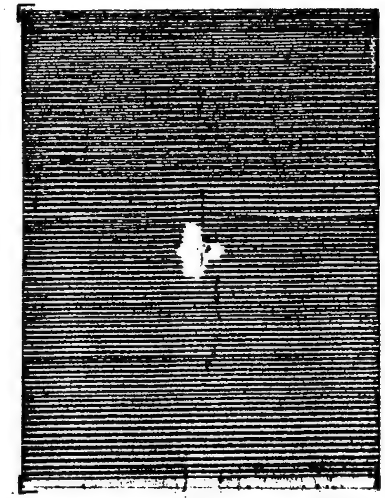
NO PRELOAD

AFTER PRELOAD

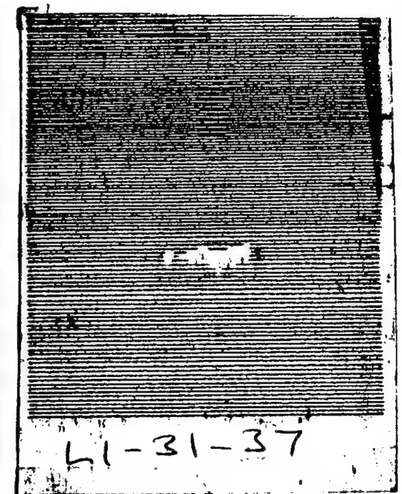
MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



10 CYCLES



10^3 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

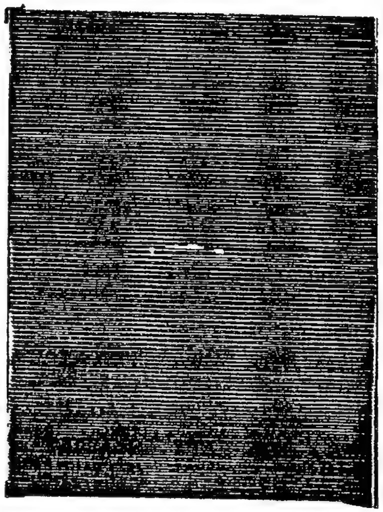
LAMINATE L1

SPECIMEN NO. L1-31-37

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



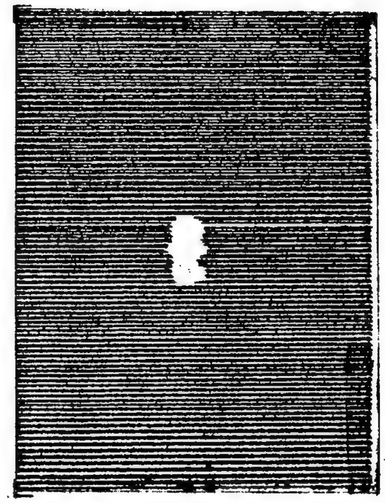
BEFORE TEST

NO PRELOAD

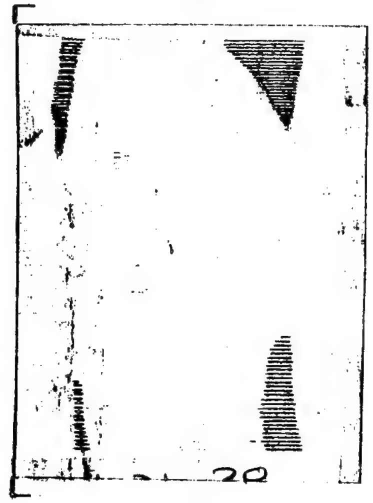
AFTER PRELOAD

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES



10^6 CYCLES

MAXIMUM LOAD —

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300 °F)

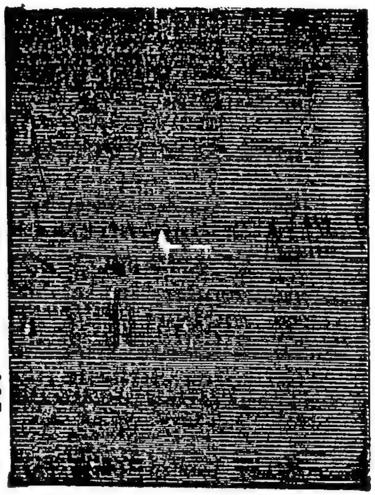
LAMINATE L1

SPECIMEN NO. L1-31-38

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

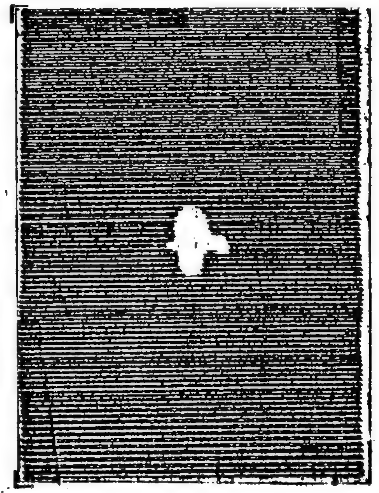
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES

CYCLIC LOAD 46.7 kN (10.5 KIP)

R RATIO 0.05

TEST TEMPERATURE 422 K (300 °F)

______ CYCLES

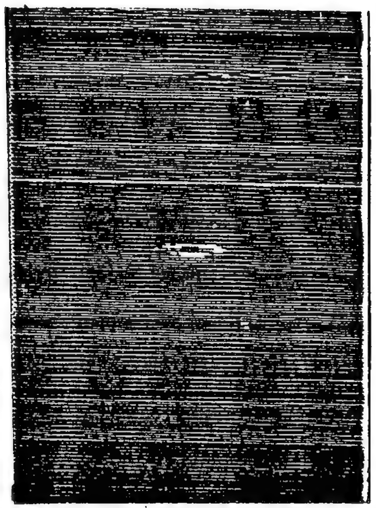
LAMINATE L1

SPECIMEN NO. L1-31-39

DEFECT 5/8 FD SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

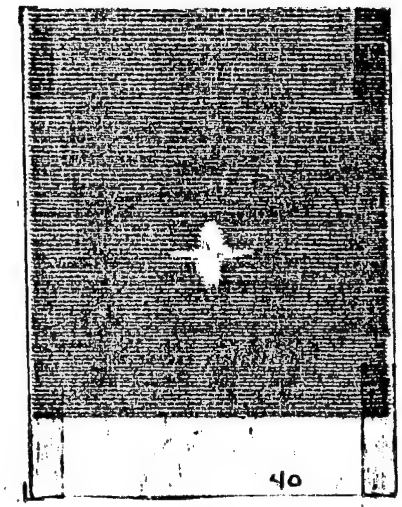
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



10 CYCLES

CYCLIC LOAD 40.0 kN (9.0 KIP)

R RATIO −1.0

TEST TEMPERATURE ROOM

____ CYCLES

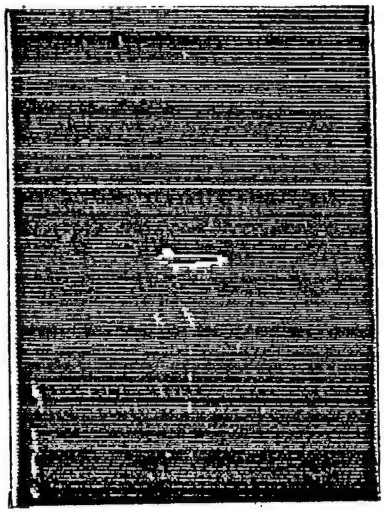
LAMINATE L1

SPECIMEN NO. L1-31-40

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

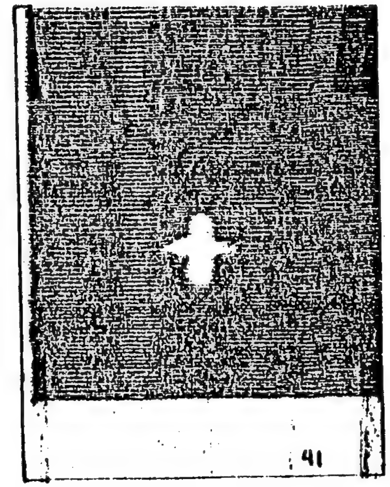
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES

____ CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-41

DEFECT 5/8 FP SLIT

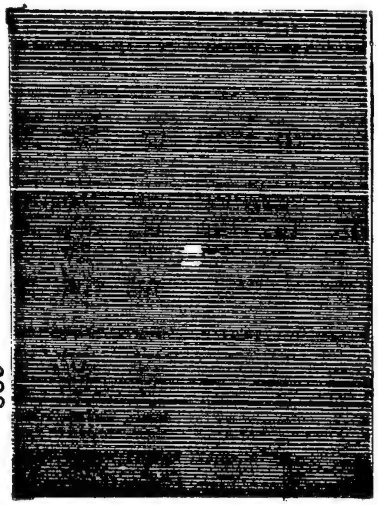
TEST TYPE CYCLIC

CYCLIC LOAD 37.8 kN (8.5 KIP)

R RATIO -1.0

TEST TEMPERATURE ROOM

ULTRASONIC C-SCAN DATA



BEFORE TEST

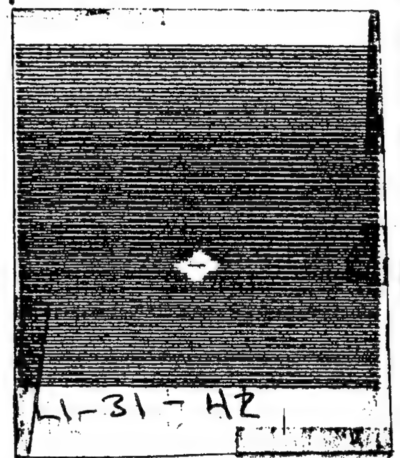
NO PRELOAD

AFTER PRELOAD

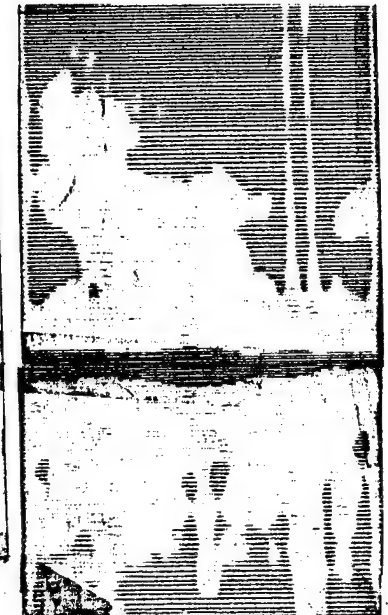
MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



10 CYCLES



25 CYCLES

CYCLIC LOAD 400 kN (9.0 kip)

R RATIO -1.0

TEST TEMPERATURE 422 K (300°F)

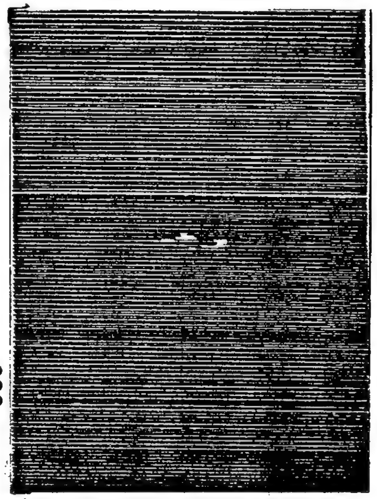
LAMINATE L1

SPECIMEN NO. L1-31-42

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

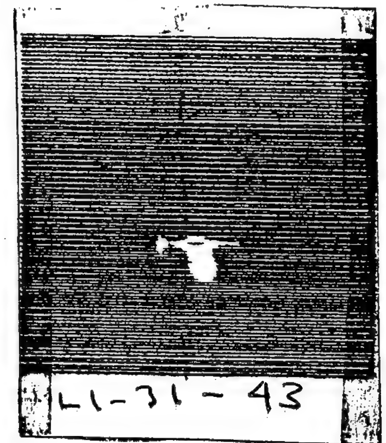
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD –

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

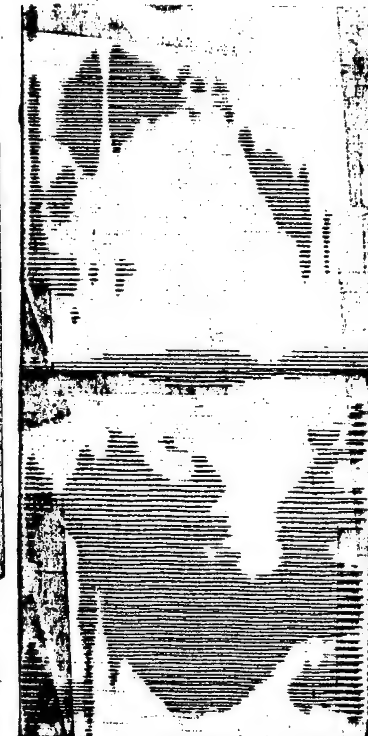


100 CYCLES

CYCLIC LOAD 40.0 kN (9.0 kip)

R RATIO -1.0

TEST TEMPERATURE 422 K (300 °F)



1750 CYCLES (FAILURE)

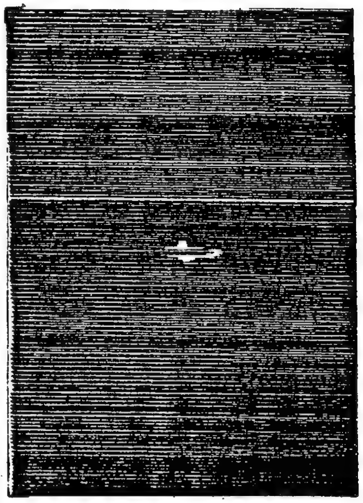
LAMINATE L1

SPECIMEN NO. L1-31-43

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

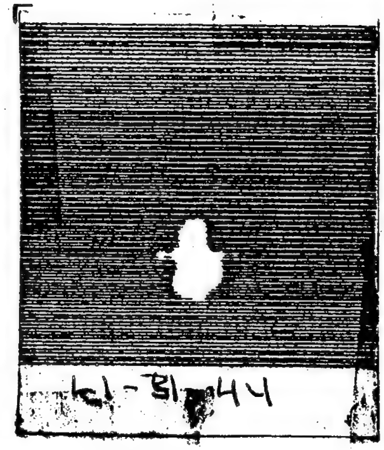
NO DEFECT

AFTER PRELOAD

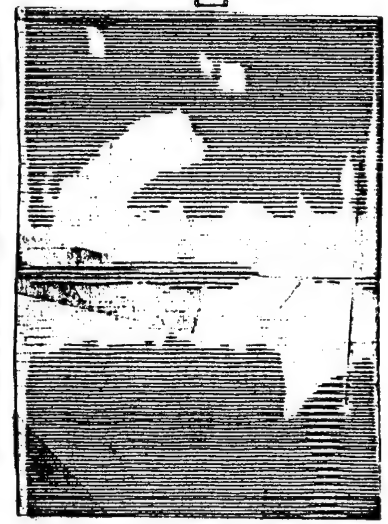
MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES



1550 CYCLES
(FAILURE)

LAMINATE L1

SPECIMEN NO. L1-31-44

DEFECT 5/8 FP SLIT

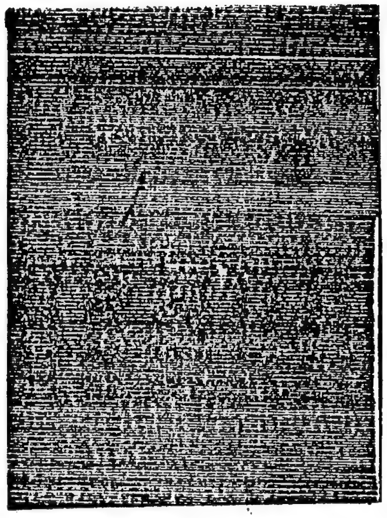
TEST TYPE CYCLIC

CYCLIC LOAD 37.8 kN (8.5 kip)

R RATIO −1.0

TEST TEMPERATURE 422 K (300 °F)

ULTRASONIC C-SCAN DATA

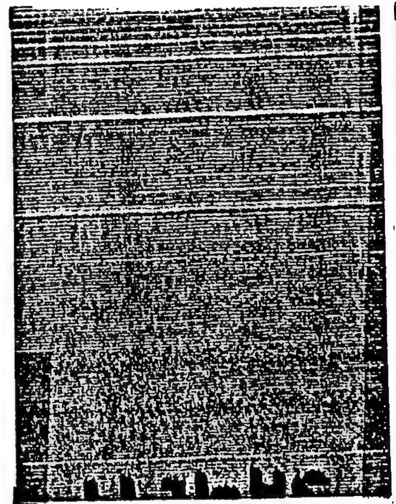


BEFORE TEST

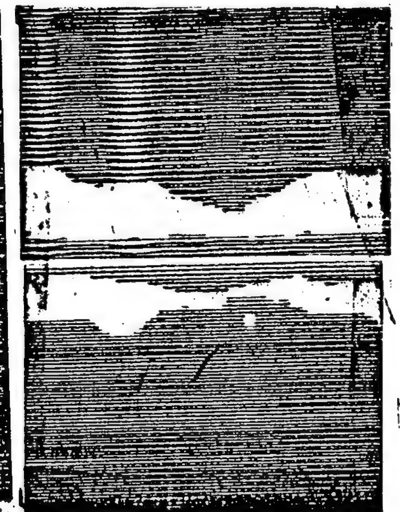
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING



1 CYCLES

~~CYCLIC~~ LOAD 28.9 kN (6.5 kip)

R RATIO -1.0

TEST TEMPERATURE 422 k (300 °F)

CYCLES

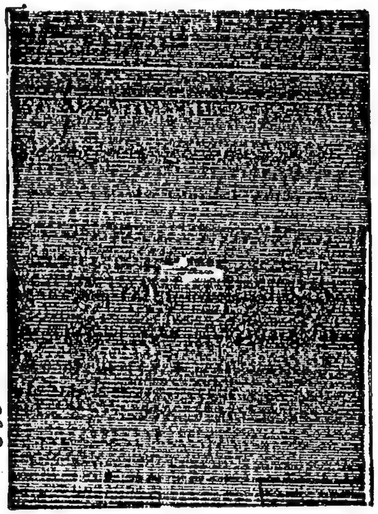
LAMINATE L1

SPECIMEN NO. L1-31-45

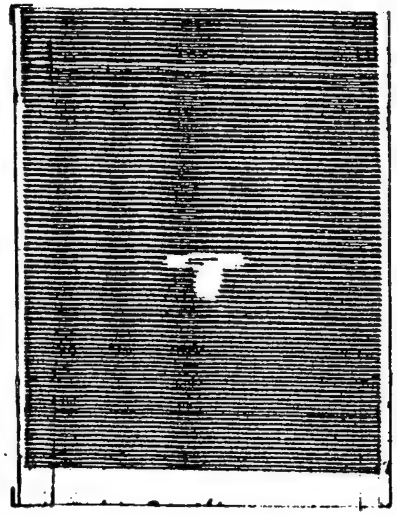
DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

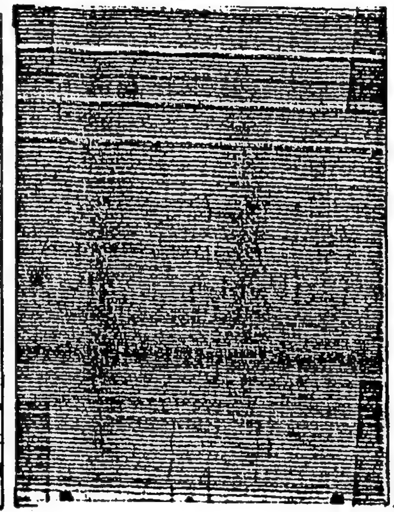
ULTRASONIC C-SCAN DATA



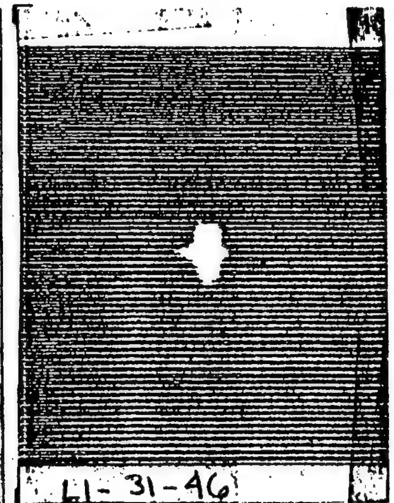
BEFORE TEST



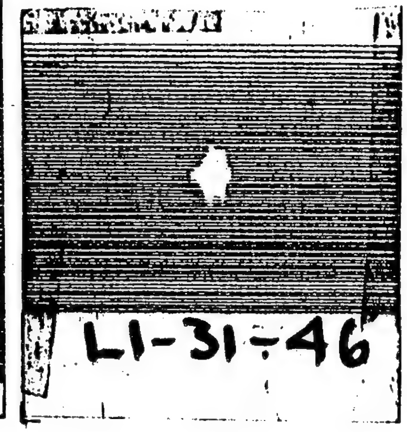
AFTER PRELOAD



AFTER MOISTURE CONDITIONING



100 CYCLES



10^5 CYCLES

MAXIMUM LOAD 48.9 kN (11.0 kip)

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE Room

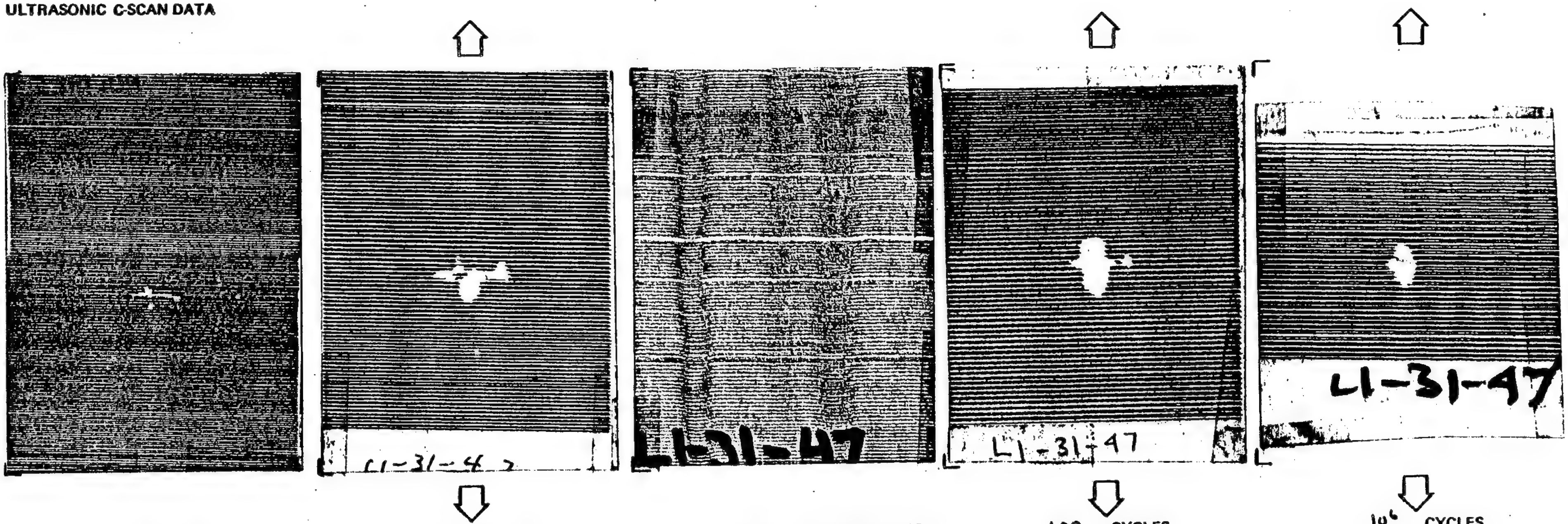
LAMINATE L1

SPECIMEN NO. L1-31-46

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

MAXIMUM LOAD 48.9kN(11.0 kip)

AFTER MOISTURE CONDITIONING

100 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE Room

10^6 CYCLES

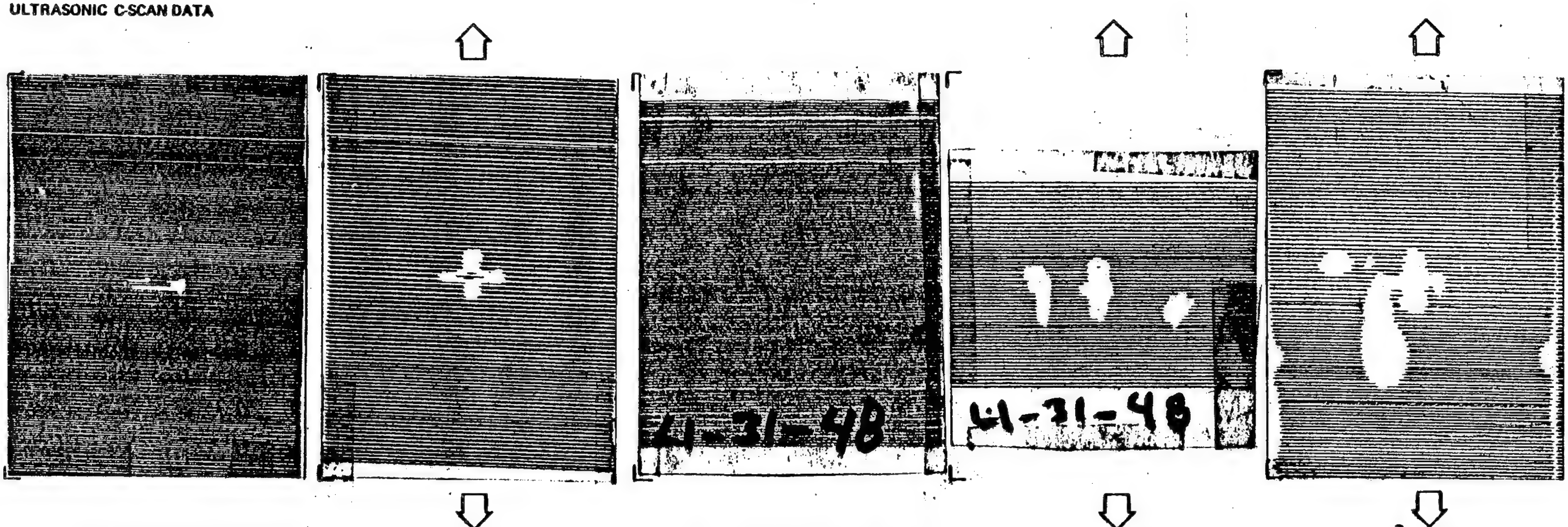
LAMINATE L1

SPECIMEN NO. L1-31-47

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | 10 CYCLES | 10^3 CYCLES

MAXIMUM LOAD 48.9 kN (11.0 kip)

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

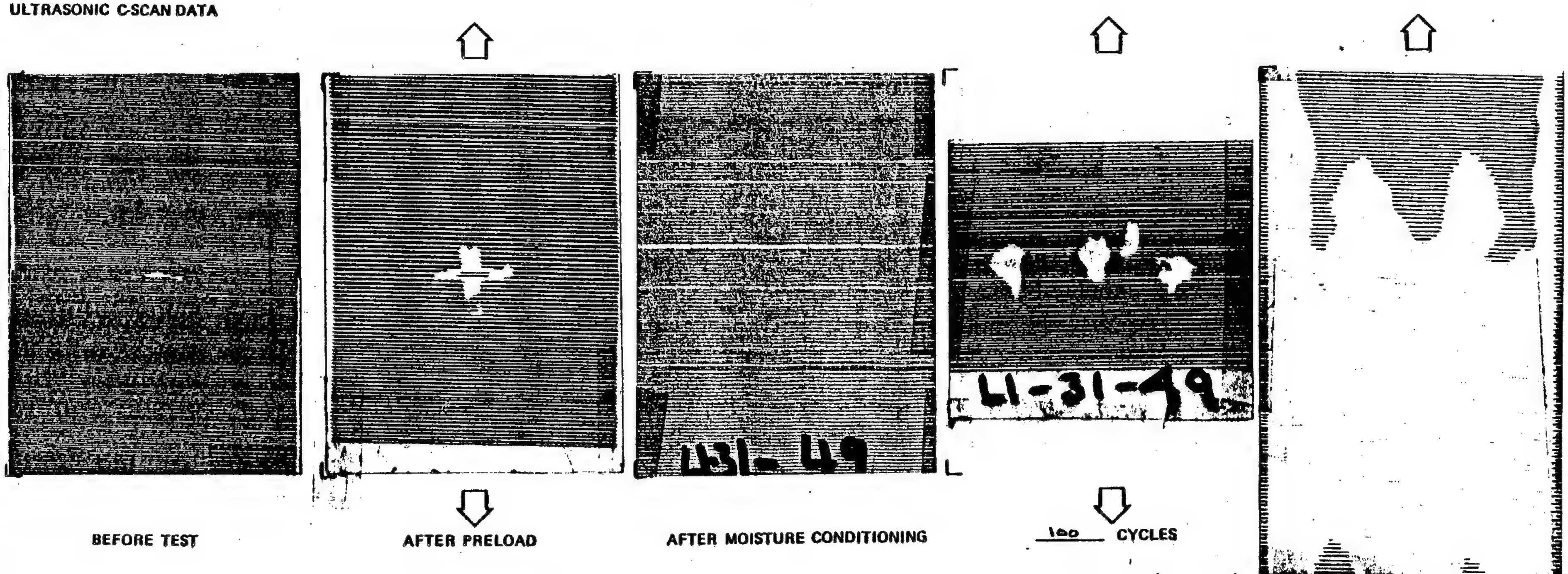
LAMINATE LI

SPECIMEN NO. LI-31-48

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

MAXIMUM LOAD 48.9kN (11.0 KIP)

AFTER MOISTURE CONDITIONING

100 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

10^6 CYCLES

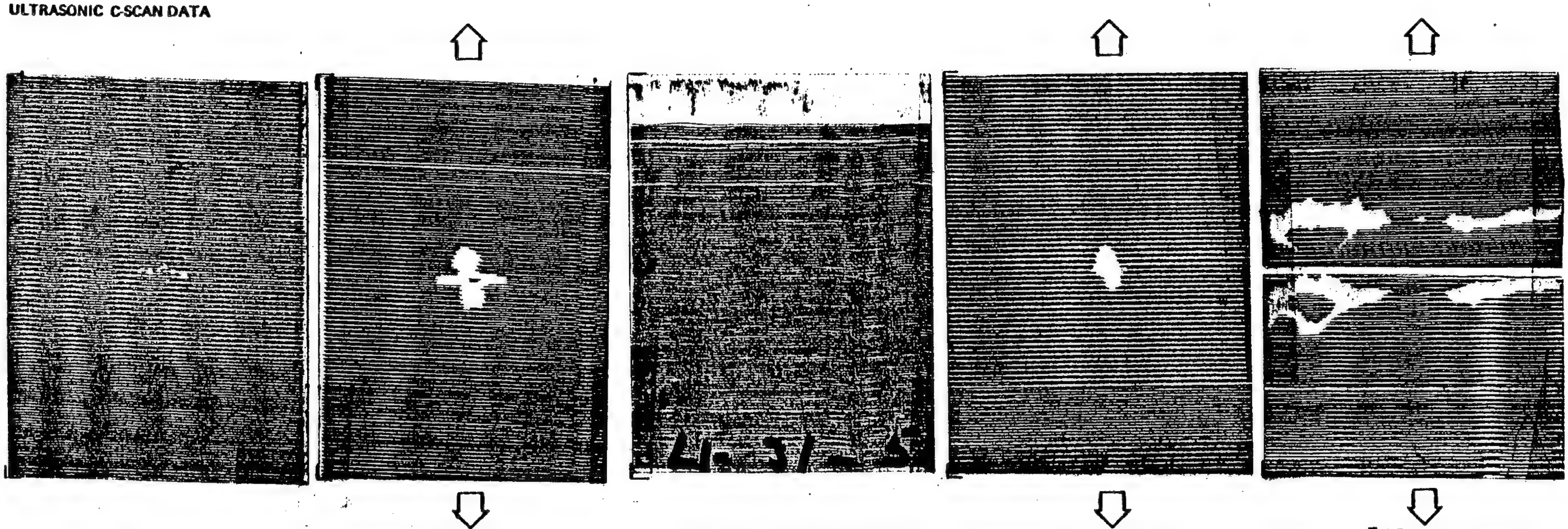
LAMINATE L1

SPECIMEN NO. L1-31-49.

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

MAXIMUM LOAD 48.9kN (11.0KIP)

AFTER MOISTURE CONDITIONING

100 CYCLES

CYCLIC LOAD 40.0 kN (9.0 KIP)

R RATIO -1.0

TEST TEMPERATURE ROOM

750 CYCLES
(FAILURE)

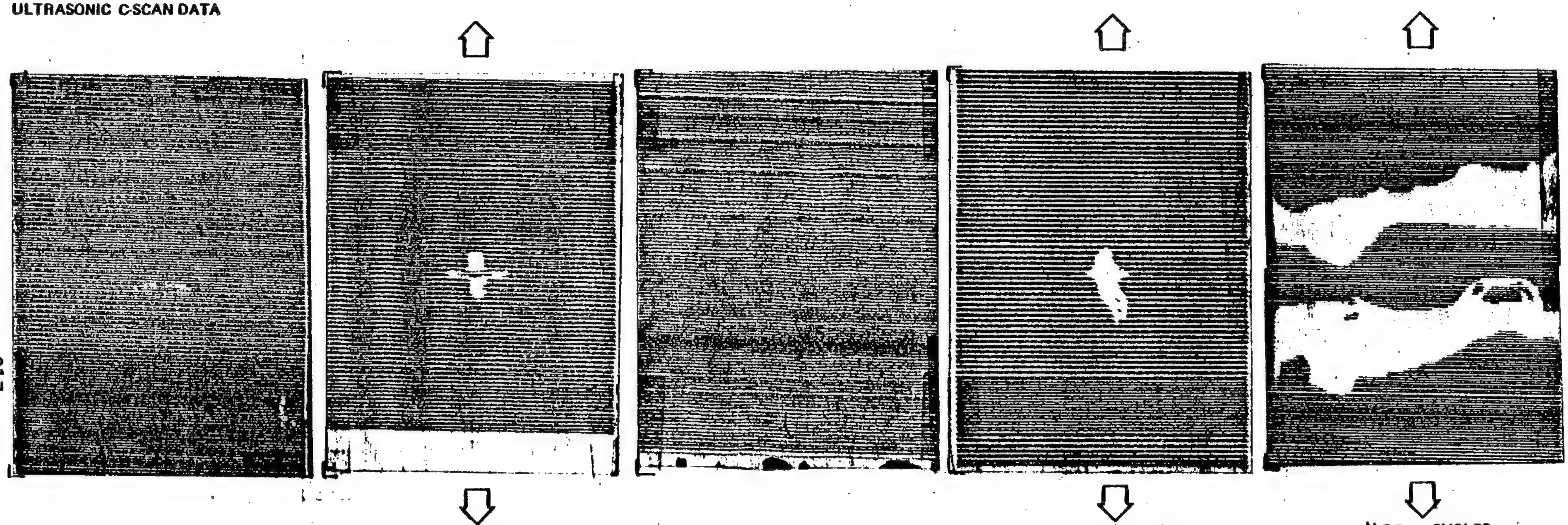
LAMINATE L1

SPECIMEN NO. L1-31-50

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | 100 CYCLES | 1100 CYCLES

MAXIMUM LOAD 48.9 kN (11.0 KIP)

CYCLIC LOAD 40.0 kN (9.0 KIP)

R RATIO -1.0

TEST TEMPERATURE ROOM

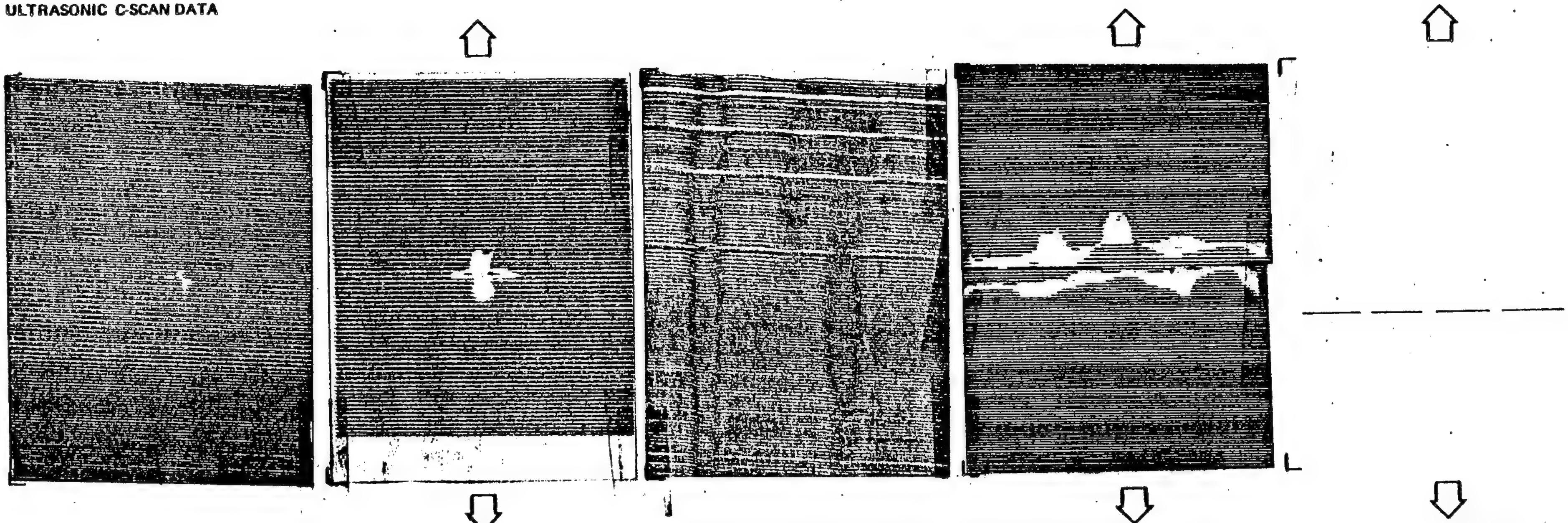
LAMINATE L1

SPECIMEN NO. L1-31-S1

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

AFTER PRELOAD

MAXIMUM LOAD 48.9kN (11.0 kip)

AFTER MOISTURE CONDITIONING

3 CYCLES

CYCLIC LOAD +33.8 kN (7.6 kip) / −34.5 kN (7.75 kip)

R RATIO −1.02

TEST TEMPERATURE 422K (300°F)

____ CYCLES

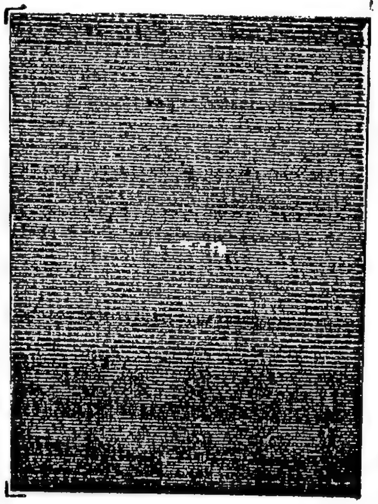
LAMINATE L1

SPECIMEN NO. L1-31-52

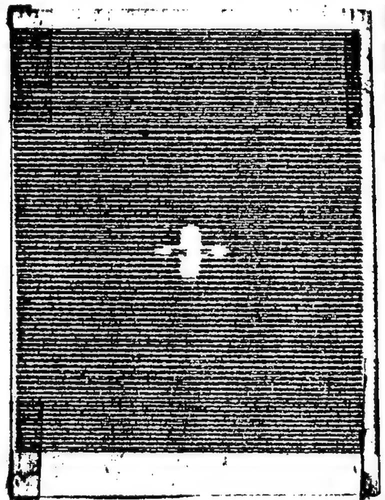
DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

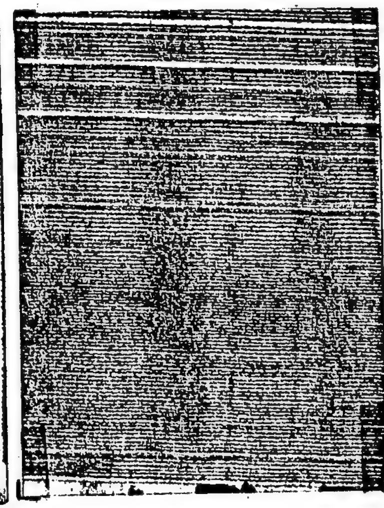
ULTRASONIC C-SCAN DATA



BEFORE TEST

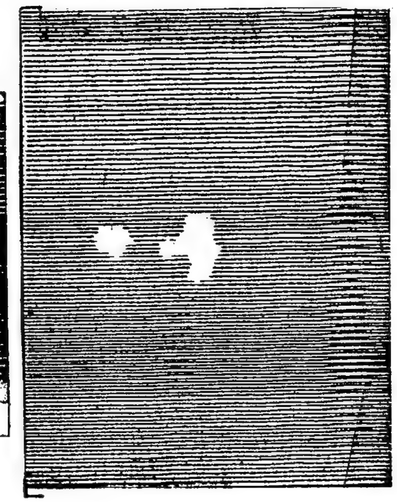


AFTER PRELOAD



AFTER MOISTURE CONDITIONING

100 CYCLES



10^6 CYCLES

MAXIMUM LOAD 48.9kN (11.0 kip)

CYCLIC LOAD 13.3kN (3.0 kip)

R RATIO -1.0

TEST TEMPERATURE 422 k (300°F)

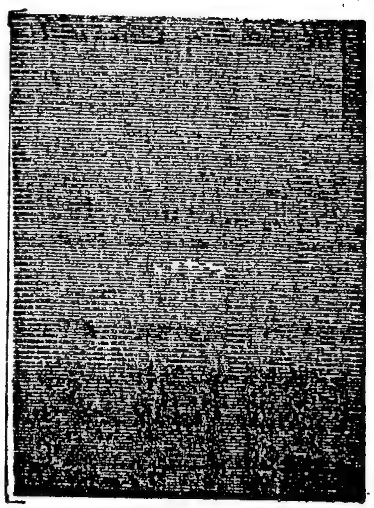
LAMINATE L1

SPECIMEN NO. L1-31-53

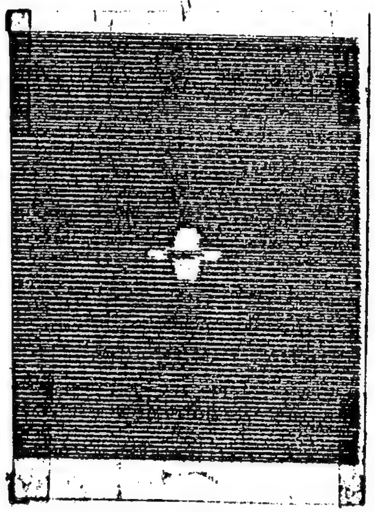
DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

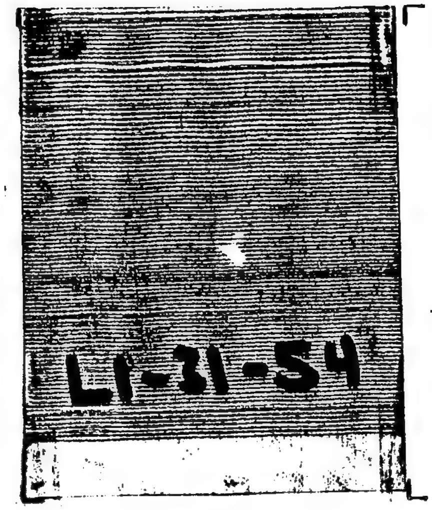


AFTER PRELOAD

MAXIMUM LOAD 48.9kN (11.0 kip)

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO .05

TEST TEMPERATURE Room

_____ CYCLES

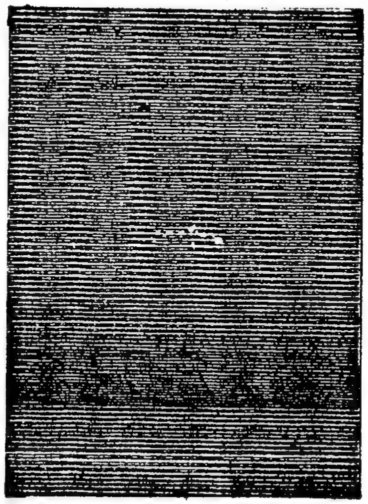
LAMINATE L1

SPECIMEN NO. L1-31-54

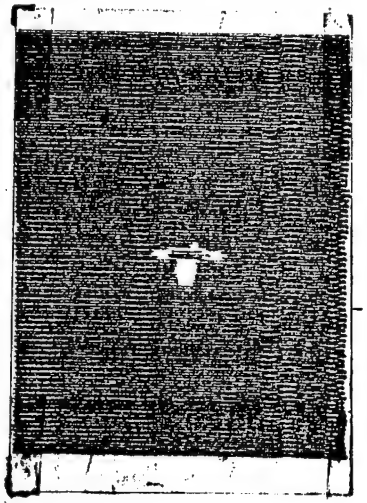
DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

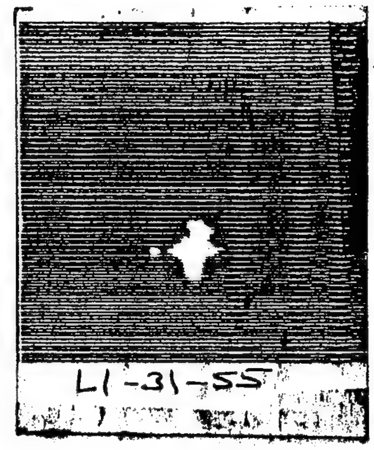


AFTER PRELOAD

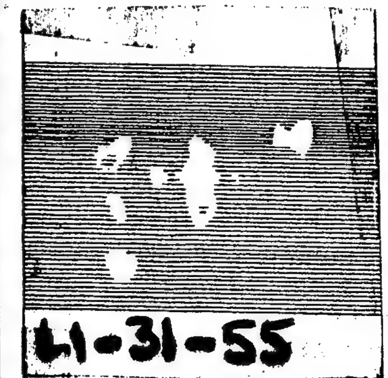
MAXIMUM LOAD 48.9 kN (11.0 kip)

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



10 CYCLES



10^3 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300 °F)

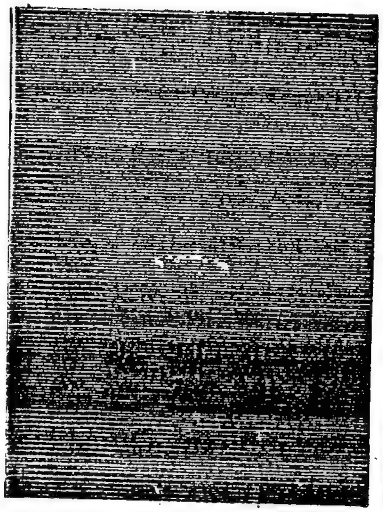
LAMINATE L1

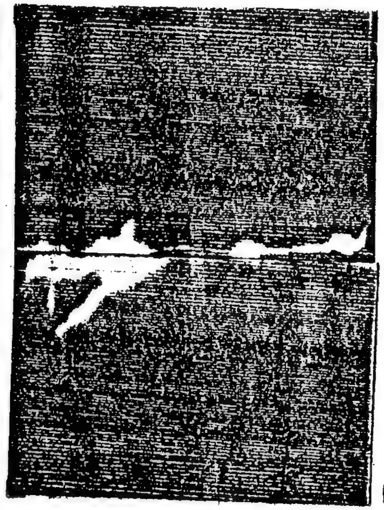
SPECIMEN NO. L1-31-55

DEFECT 5/8 PP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA





BEFORE TEST

AFTER PRELOAD FAILURE

MAXIMUM LOAD 45.3kN (10.2) kip

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

____ CYCLES

____ CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-56

DEFECT 5/8 FP SLIT

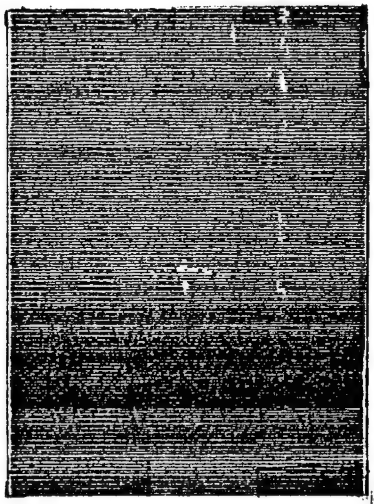
TEST TYPE CYCLIC (FAILURE DURING PRELOAD)

CYCLIC LOAD ____

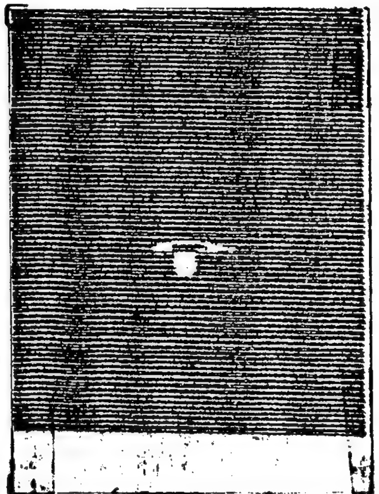
R RATIO ____

TEST TEMPERATURE ____

ULTRASONIC C-SCAN DATA



BEFORE TEST

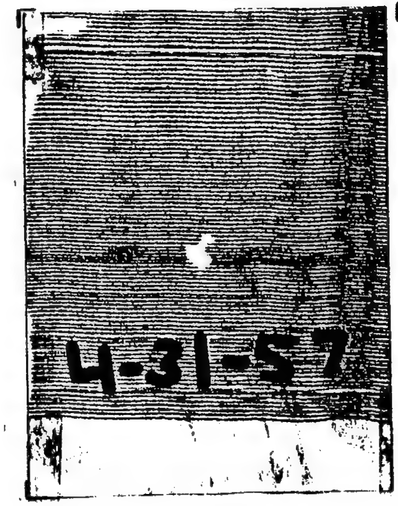


AFTER PRELOAD

MAXIMUM LOAD 48.9kN (11.0 kip)

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES

CYCLIC LOAD 37.8 kN (8.5 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM

______ CYCLES

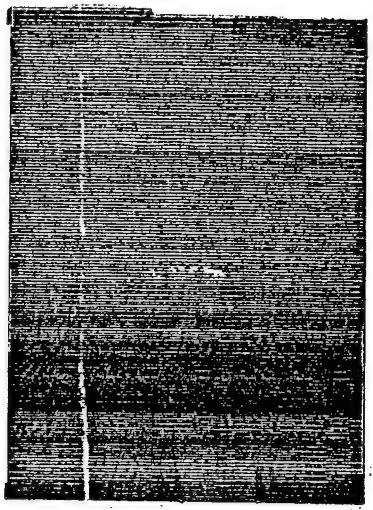
LAMINATE L1

SPECIMEN NO. L1-31-57

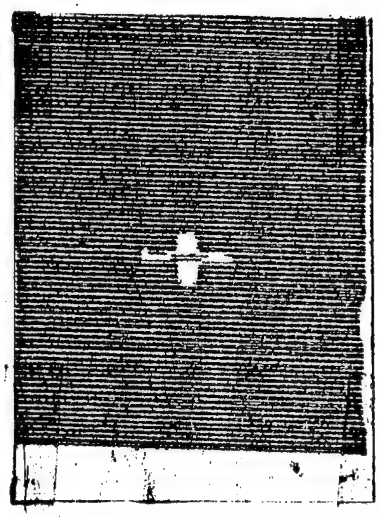
DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST



AFTER PRELOAD

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

____ CYCLES
3 CYCLES TO FAILURE

____ CYCLES

MAXIMUM LOAD 48.9 kN (11.0 KIP)

CYCLIC LOAD 40.0 kN (9.0 KIP)

R RATIO -1.0

TEST TEMPERATURE 422 K (300 °F)

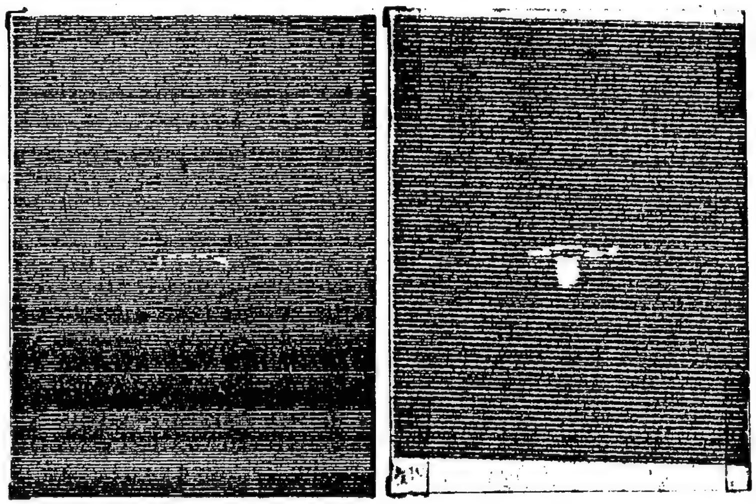
LAMINATE L1

SPECIMEN NO. L1-31-58

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST	AFTER PRELOAD	AFTER MOISTURE CONDITIONING	___ CYCLES	___ CYCLES
		NOT CONDITIONED	≥ CYCLES TO FAILURE	

MAXIMUM LOAD 48.9 kN (11.0 kip)

CYCLIC LOAD 39.1 kN (8.8 kip)

R RATIO -1.0

TEST TEMPERATURE 422 k (300 °F)

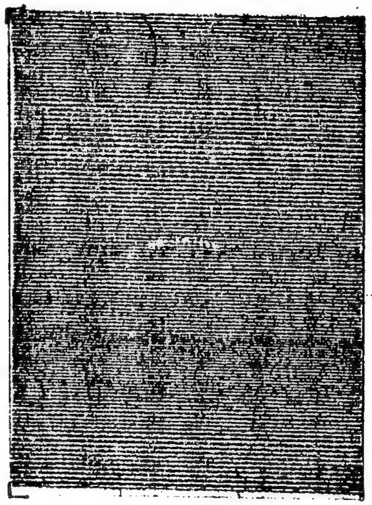
LAMINATE L1

SPECIMEN NO. L1-31-59

DEFECT 5/8 FP SLIT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

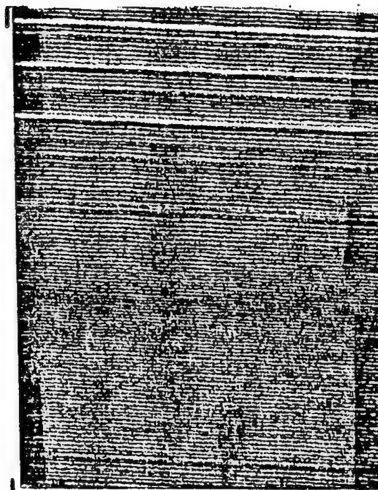


BEFORE TEST

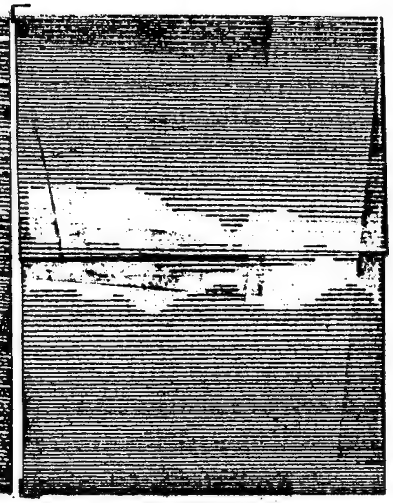
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD –



AFTER MOISTURE CONDITIONING



1 CYCLES

CYCLIC LOAD +21.84 kN (4.91) −21.9 kN (4.93)

R RATIO

TEST TEMPERATURE 422 K (300°F)

CYCLES

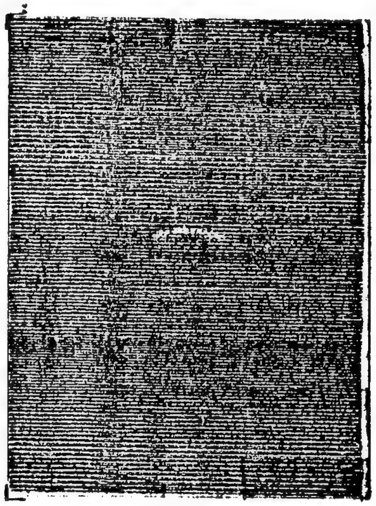
LAMINATE L1

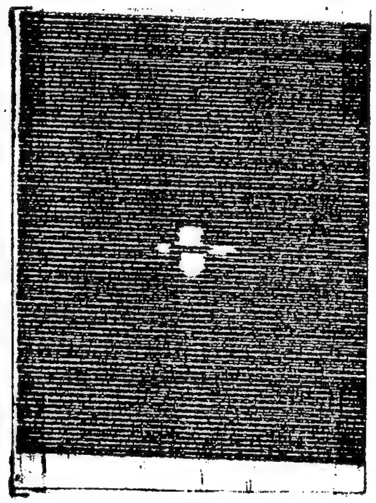
SPECIMEN NO. L1-31-60

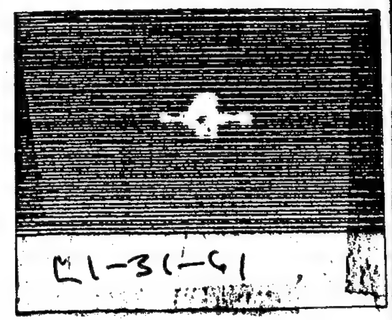
DEFECT 5/8 FP SLIT

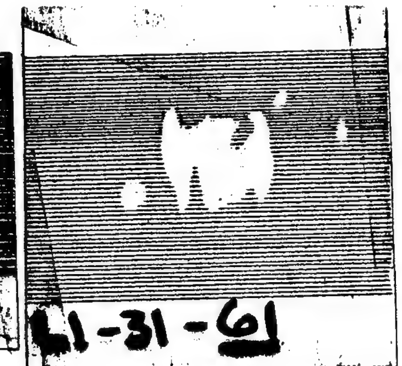
TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA









BEFORE TEST

AFTER PRELOAD

MAXIMUM LOAD 48.9kN (11.0 KIP)

AFTER MOISTURE CONDITIONING

100 CYCLES

10^6 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300 °F)

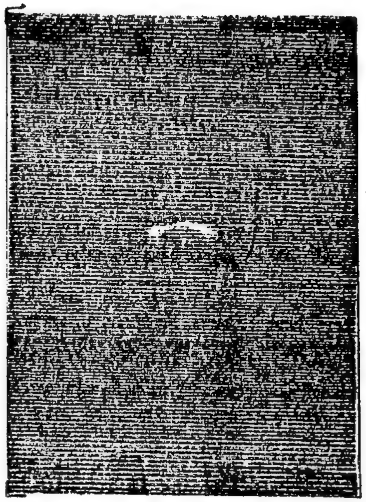
LAMINATE L1

SPECIMEN NO. L1-31-61

DEFECT 5/8 FP DEFECT

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



NO PRELOAD

NOT CONDITIONED

NOT CYCLED

BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

MAXIMUM LOAD _____

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

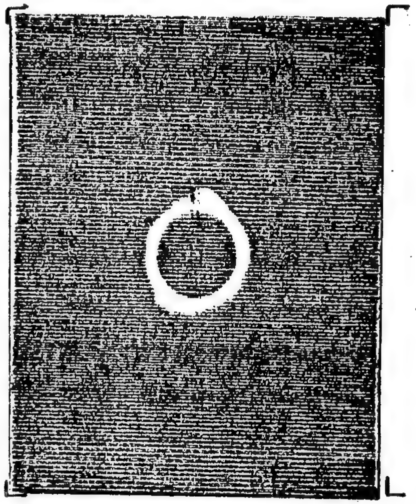
LAMINATE L1

SPECIMEN NO. L1-31-62

DEFECT 5/8 FP SLIT

TEST TYPE DRY RT TENSION

ULTRASONIC C-SCAN DATA



NO PRELOAD

NOT CONDITIONED

NOT CYCLED

BEFORE TEST

AFTER PRELOAD

AFTER MOISTURE CONDITIONING

_____ CYCLES

_____ CYCLES

MAXIMUM LOAD —

CYCLIC LOAD _____

R RATIO _____

TEST TEMPERATURE _____

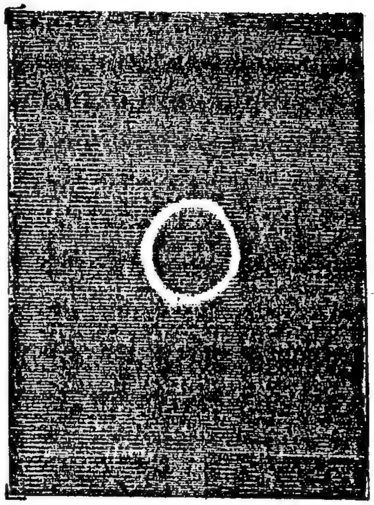
LAMINATE L1

SPECIMEN NO. L1-31-63

DEFECT 5/8 FP HOLE

TEST TYPE STATIC RT TENSION

ULTRASONIC C-SCAN DATA

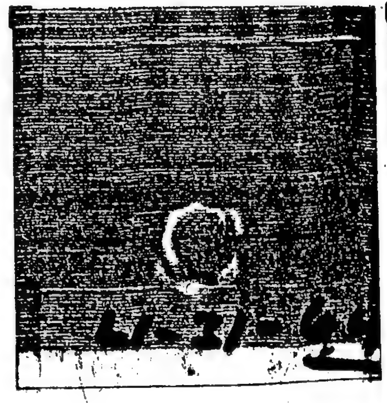


BEFORE TEST

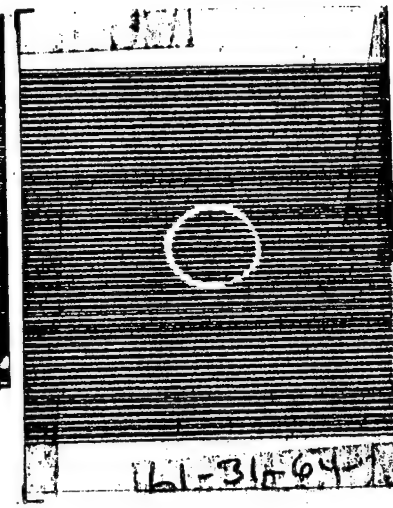
NO PRELOAD

AFTER PRELOAD

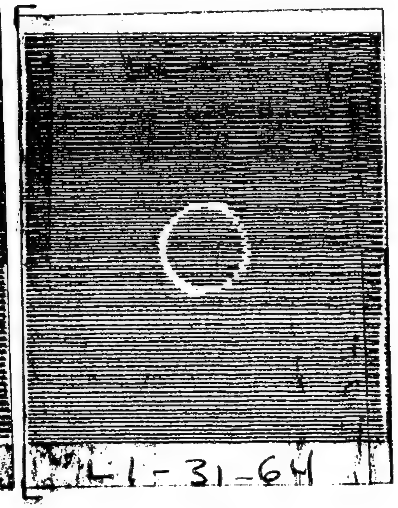
MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING



10 CYCLES



10^3 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE ROOM

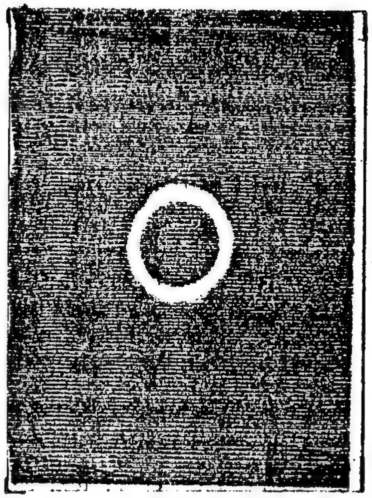
LAMINATE L1

SPECIMEN NO. L1-31-64

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

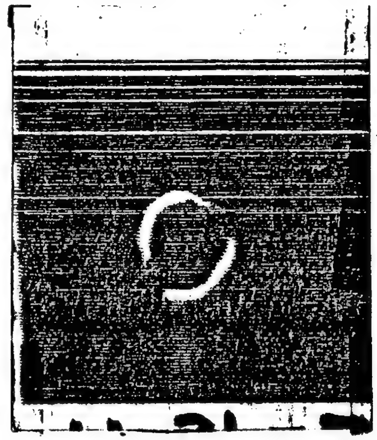
ULTRASONIC C-SCAN DATA



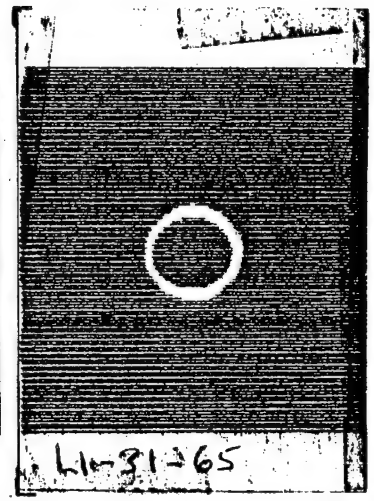
BEFORE TEST

NO PRELOAD

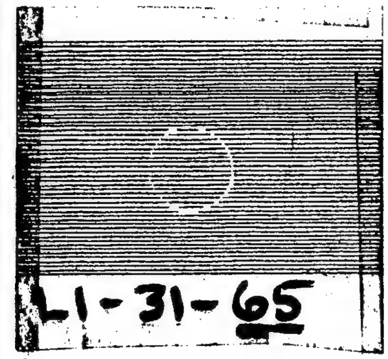
AFTER PRELOAD



AFTER MOISTURE CONDITIONING



10^2 CYCLES



10^6 CYCLES

MAXIMUM LOAD —

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE ROOM

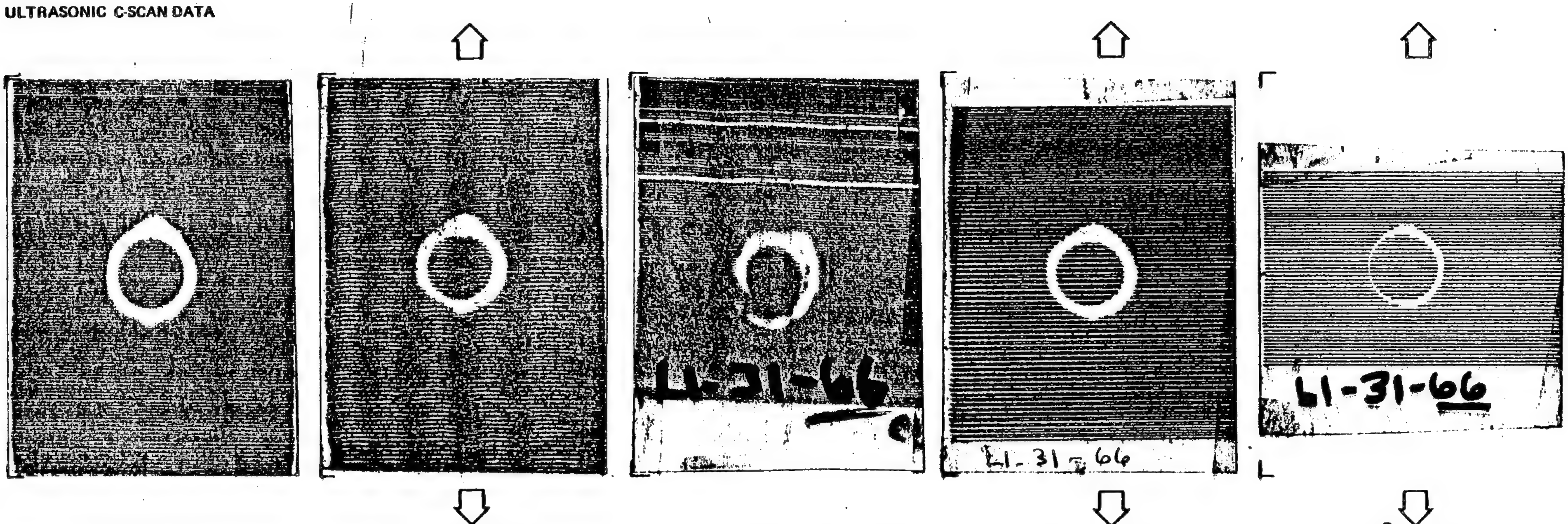
LAMINATE L1

SPECIMEN NO. L1-31-65

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | 10 CYCLES | 10^3 CYCLES

MAXIMUM LOAD 48.9 kN (11.0 KIP)

CYCLIC LOAD 46.7 kN (10.5 KIP)

R RATIO 0.05

TEST TEMPERATURE ROOM

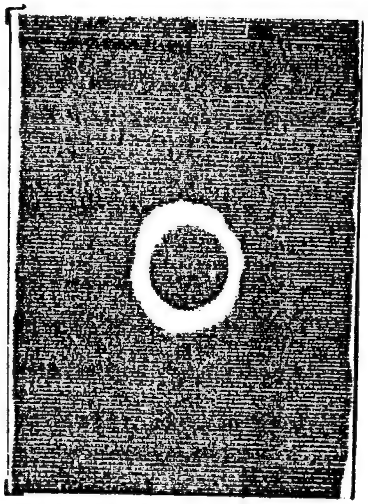
LAMINATE L1

SPECIMEN NO. L1-31-66

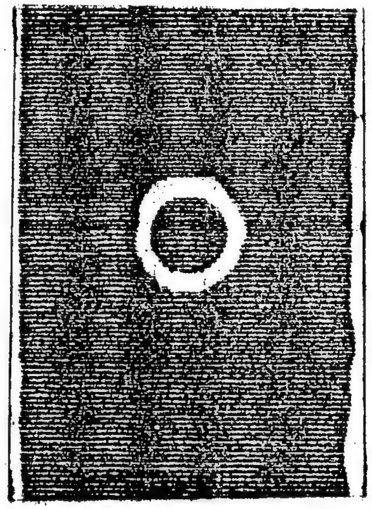
DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

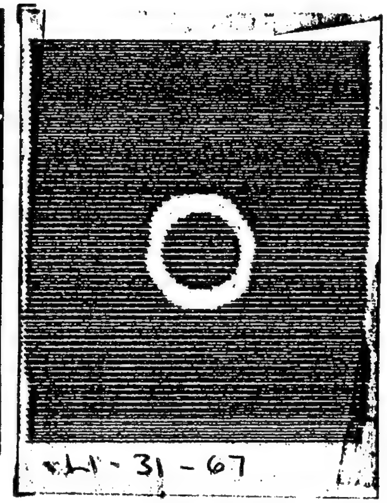


BEFORE TEST

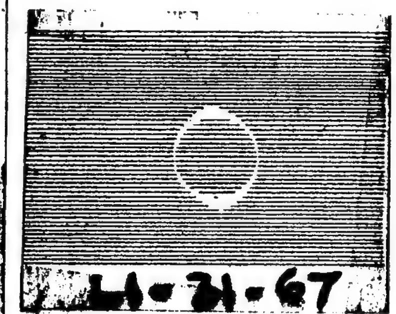


AFTER PRELOAD

AFTER MOISTURE CONDITIONING



100 CYCLES



10^6 CYCLES

MAXIMUM LOAD 48.9kN (11.0 kip)

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE ROOM

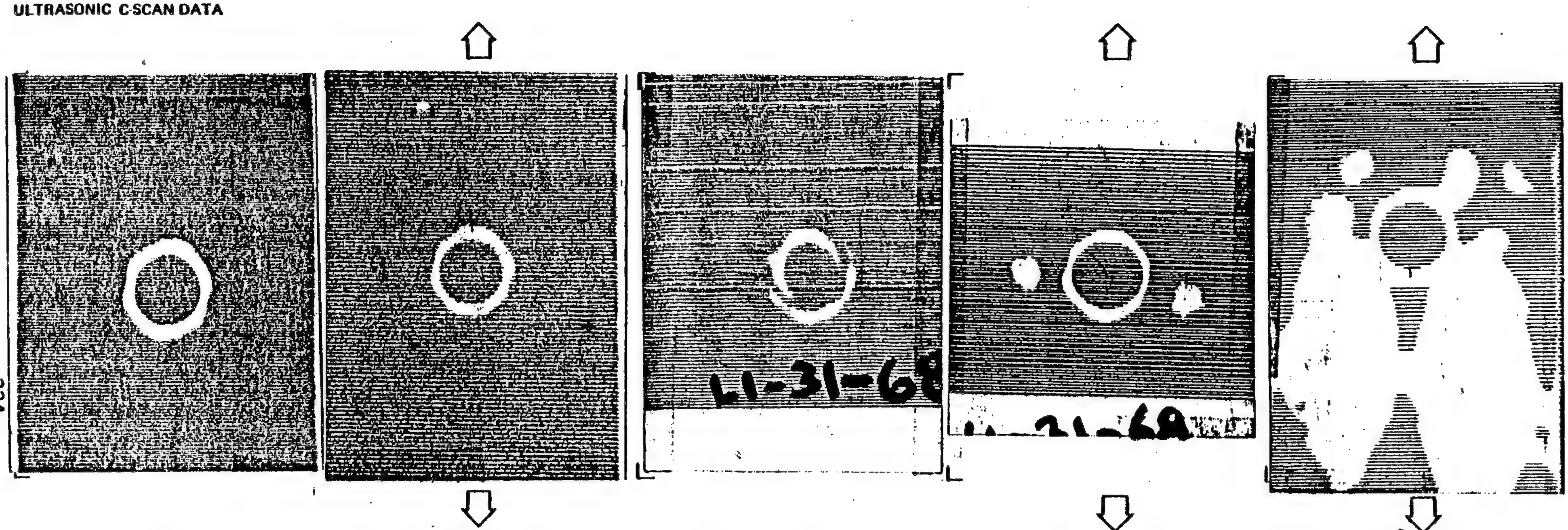
LAMINATE L1

SPECIMEN NO. L1-31-67

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | 10 CYCLES | 10^3 CYCLES

MAXIMUM LOAD 48.9 kN (11.0 kip)

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

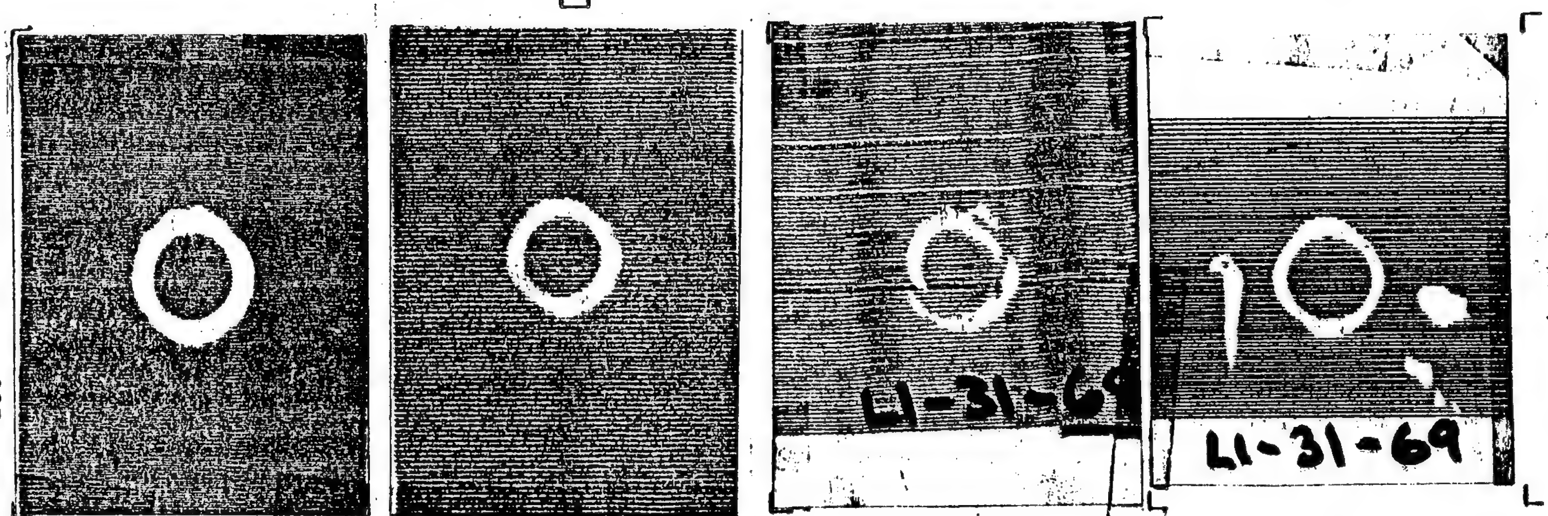
LAMINATE L1

SPECIMEN NO. L1-31-68

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | 10 CYCLES | ______ CYCLES

MAXIMUM LOAD 48.9kN (11.0KIP)

CYCLIC LOAD 46.7kN (10.5 KIP)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

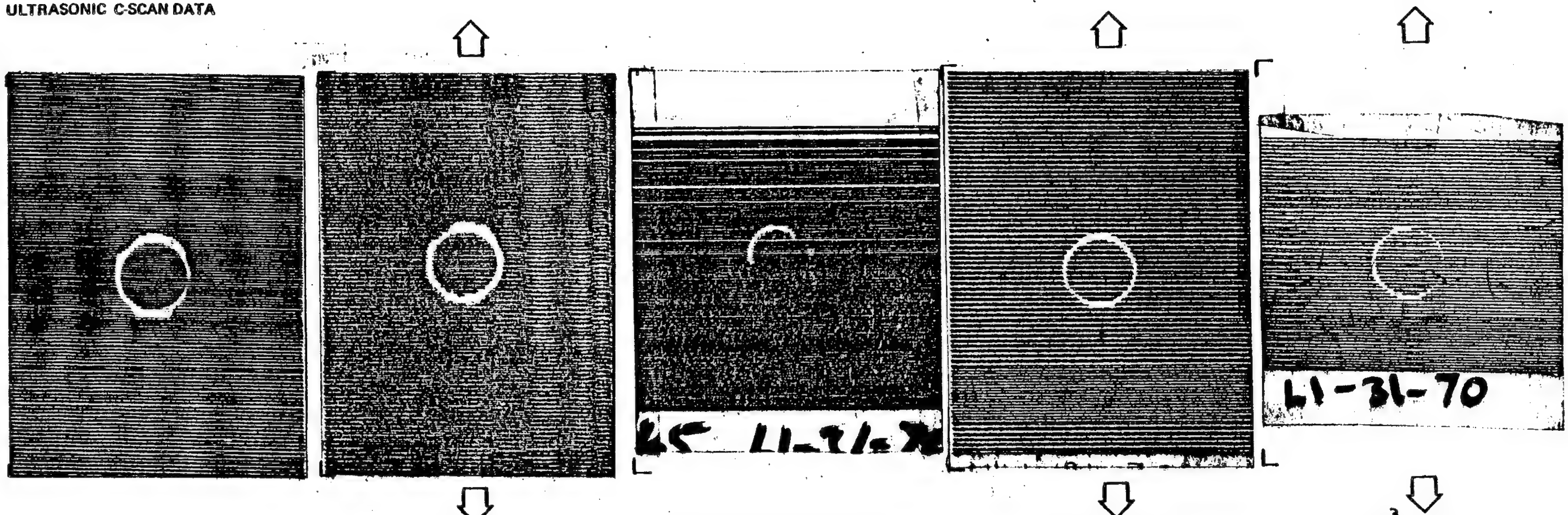
LAMINATE L1

SPECIMEN NO. L1-31-69

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | 10 CYCLES | 10^3 CYCLES

MAXIMUM LOAD 48.9kN (11.0KIP)

CYCLIC LOAD 40.0 (9.0KIP)

R RATIO -1.0

TEST TEMPERATURE ROOM

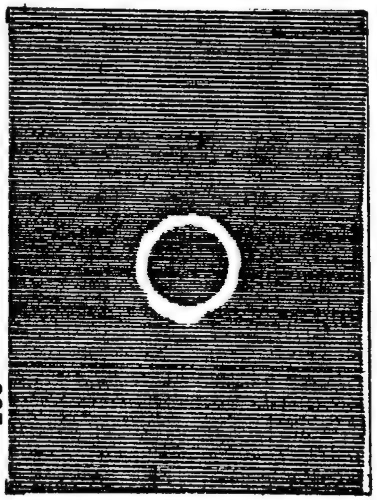
LAMINATE L1

SPECIMEN NO. L1-31-70

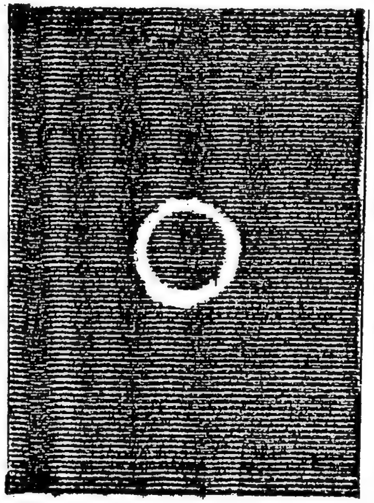
DEFECT L1-31-70

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

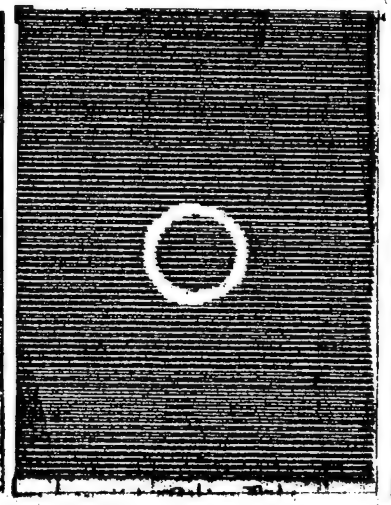


BEFORE TEST

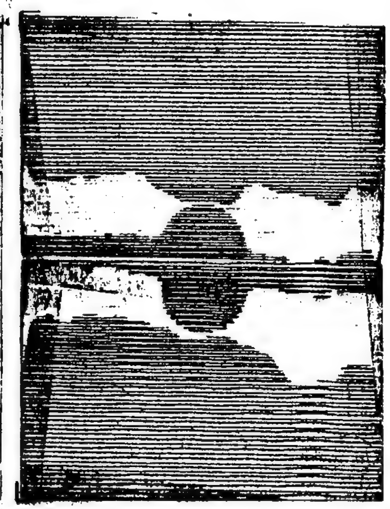


AFTER PRELOAD

AFTER MOISTURE CONDITIONING



100 CYCLES



1250 CYCLES (FAILURE)

MAXIMUM LOAD 48.9 kN (11.0 KIP)

CYCLIC LOAD 40.0 kN (9.0 KIP)

R RATIO -1.0

TEST TEMPERATURE ROOM

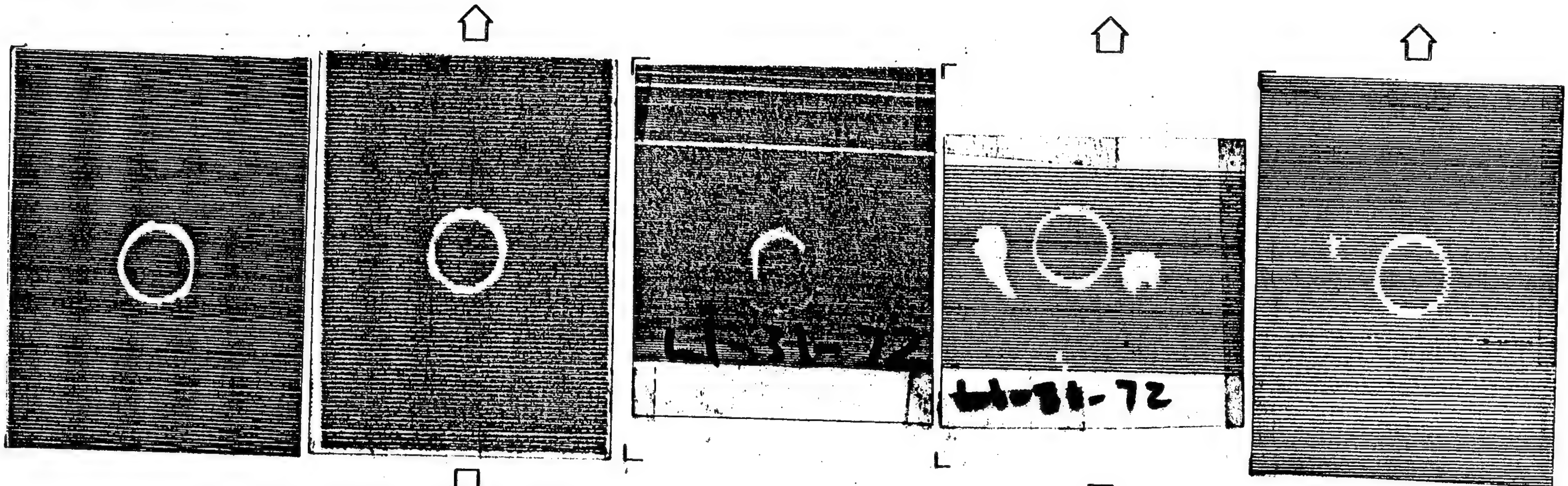
LAMINATE L1

SPECIMEN NO. L1-31-71

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | 10 CYCLES | 10^3 CYCLES

MAXIMUM LOAD 48.9 kN (11.0 kip)

LAMINATE L1

SPECIMEN NO. L1-31-72

DEFECT 5/8 FP HOLE

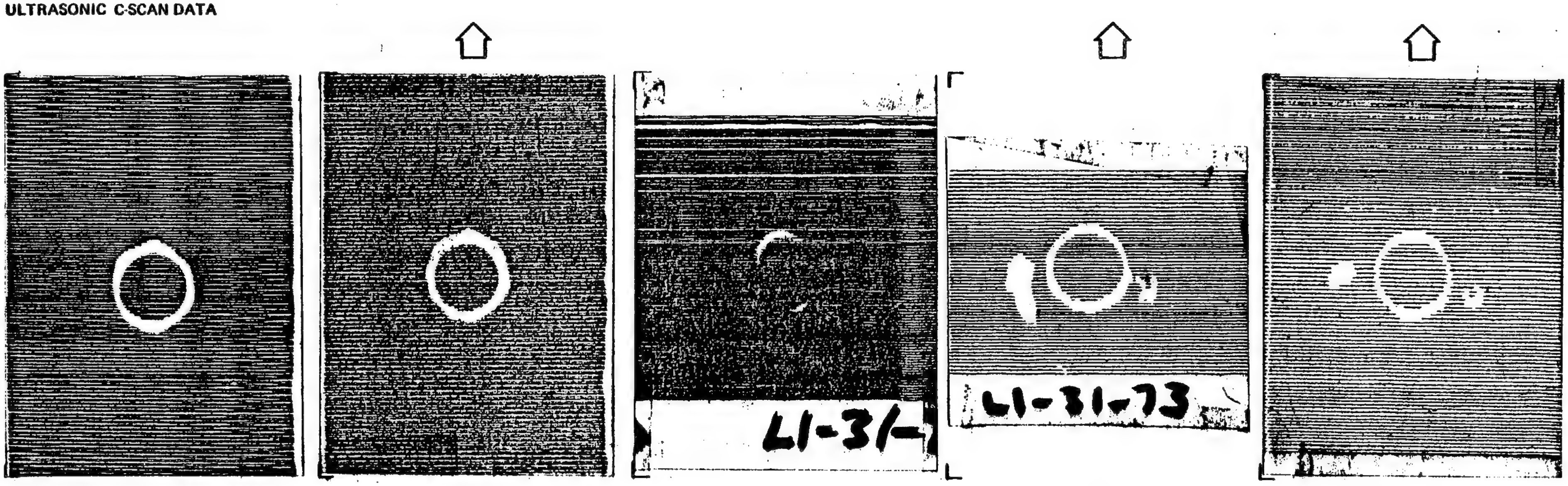
TEST TYPE CYCLIC

CYCLIC LOAD 13.3 kN (3.0 kip)

R RATIO −1.0

TEST TEMPERATURE 422 K (300°F)

ULTRASONIC C-SCAN DATA



BEFORE TEST | AFTER PRELOAD | AFTER MOISTURE CONDITIONING | 100 CYCLES | 10^6 CYCLES

MAXIMUM LOAD 48.9kN (11.0 kip)

CYCLIC LOAD 13.3 kN (3.0 kip)

R RATIO −1.0

TEST TEMPERATURE 422K (300°F)

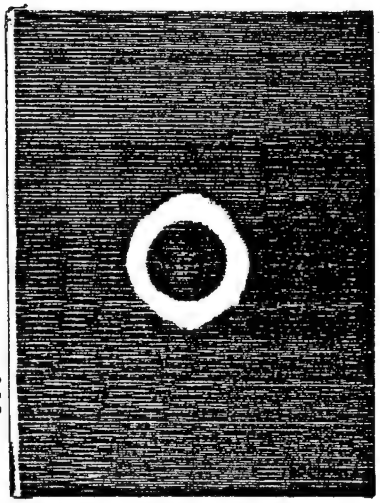
LAMINATE L1

SPECIMEN NO. L1-31-73

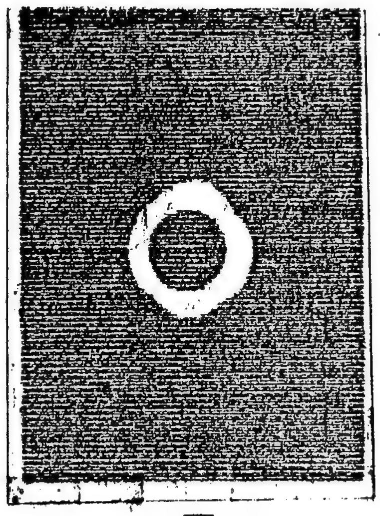
DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST



AFTER PRELOAD

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

100 CYCLES

______ CYCLES

MAXIMUM LOAD 48.9 kN (11.0 kip)

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO .05

TEST TEMPERATURE ROOM

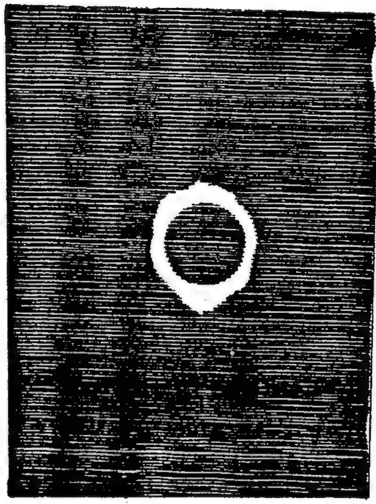
LAMINATE L1

SPECIMEN NO. L1-31-74

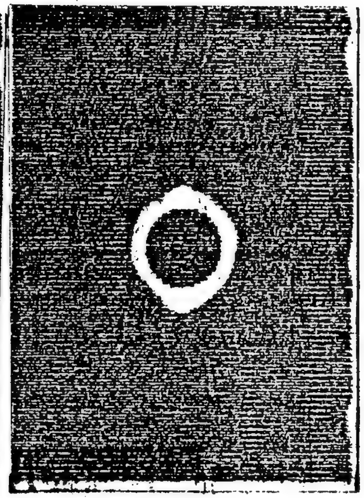
DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST



AFTER PRELOAD

MAXIMUM LOAD 48.9 kN (11.0 kip)

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

10 CYCLES

10^2 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

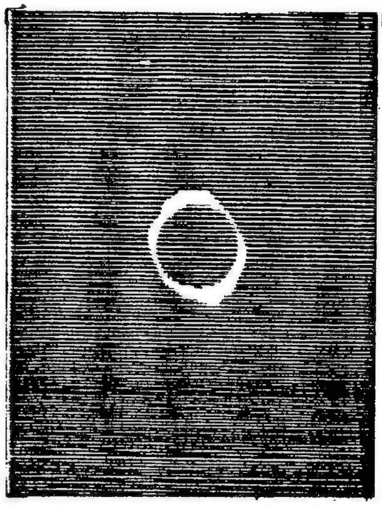
LAMINATE L1

SPECIMEN NO. L1-31-75

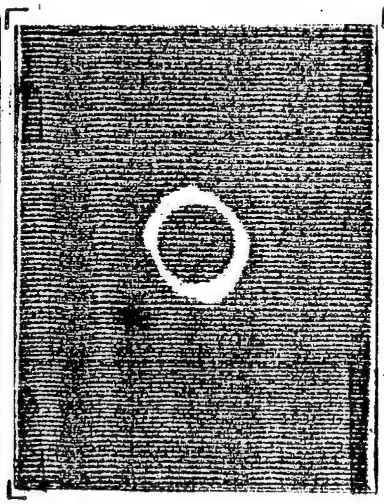
DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

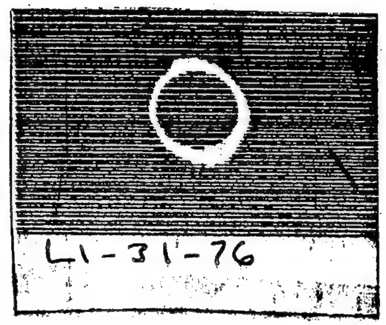


AFTER PRELOAD

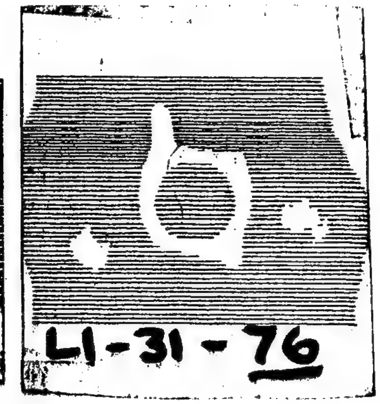
MAXIMUM LOAD 48.9 kN (11.0 KIP)

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES



10^6 CYCLES

CYCLIC LOAD 46.7 kN (10.5 KIP)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

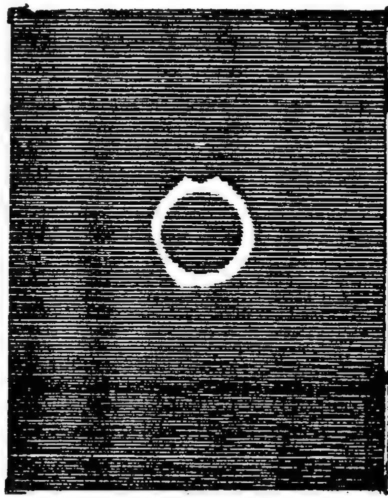
LAMINATE L1

SPECIMEN NO. L1-31-76

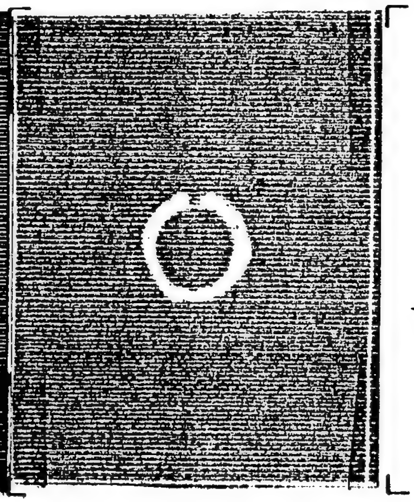
DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

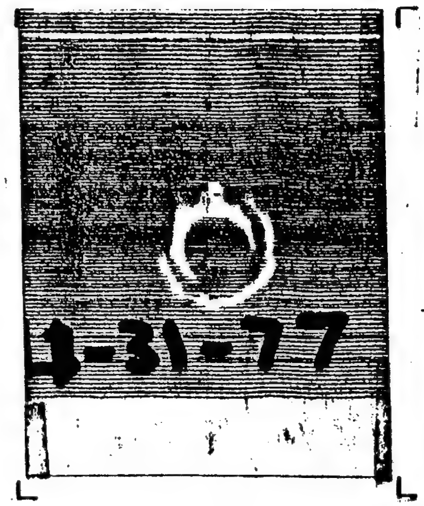


AFTER PRELOAD

MAXIMUM LOAD 48.9 kN (11.0 kip)

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES

CYCLIC LOAD 37.8 kN (8.5 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM

______ CYCLES

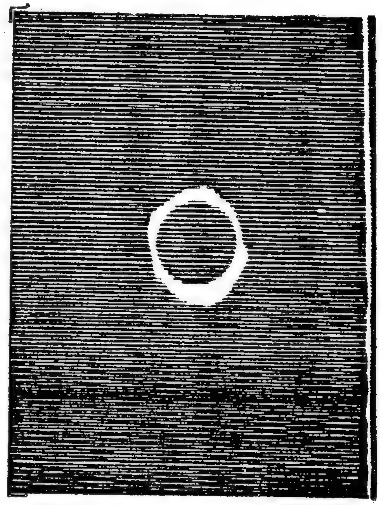
LAMINATE L1

SPECIMEN NO. L1-31-77

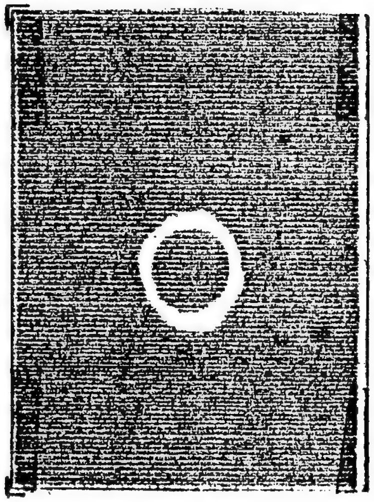
DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

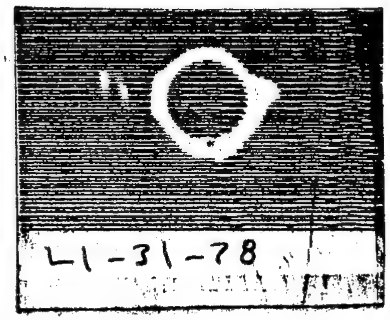


AFTER PRELOAD

MAXIMUM LOAD 48.9 kN (11.0 KIP)

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

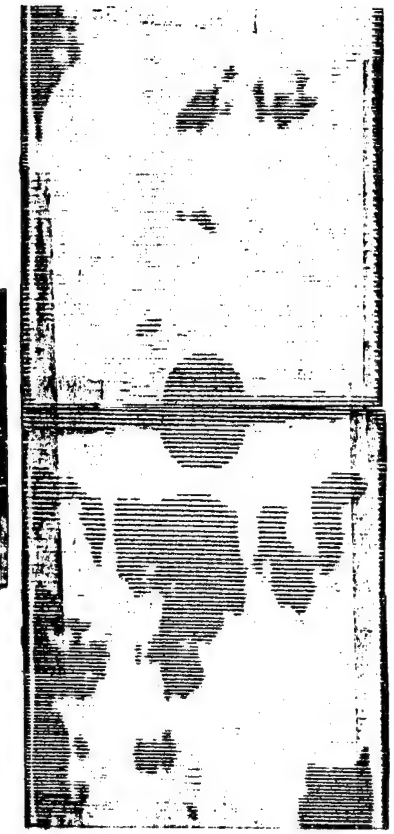


10 CYCLES

CYCLIC LOAD 40.0 kN (9.0 KIP)

R RATIO -1.0

TEST TEMPERATURE 422 K (300°F)



197 CYCLES (FAILURE)

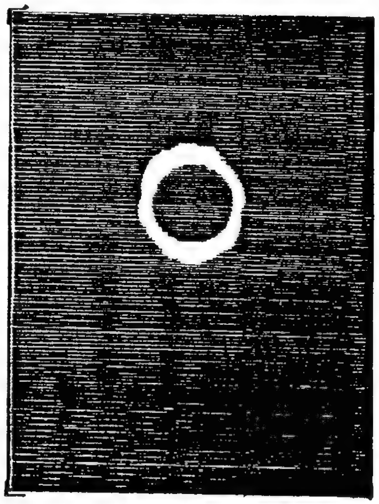
LAMINATE L1

SPECIMEN NO. L1-31-78

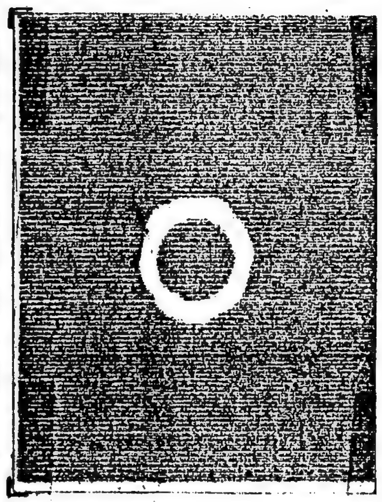
DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

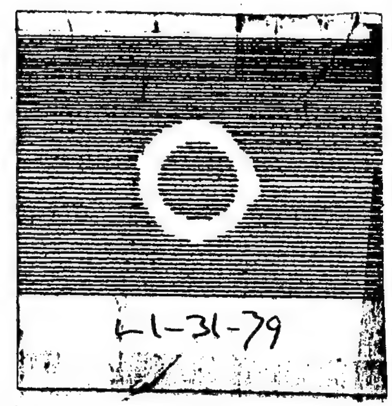


AFTER PRELOAD

MAXIMUM LOAD 48.9kN (11.0 KIP)

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

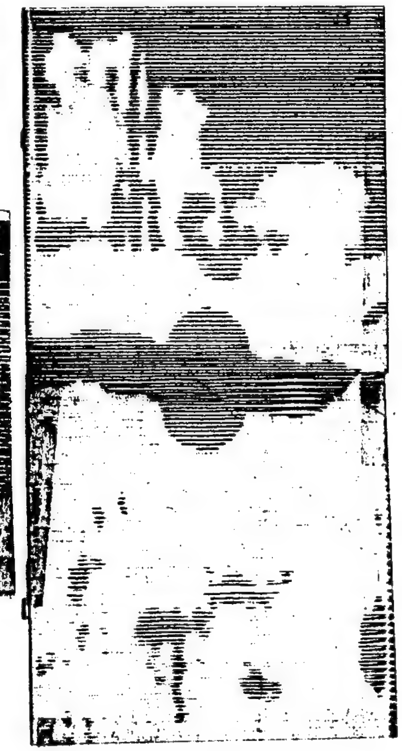


_____ CYCLES

CYCLIC LOAD 40.0 kN (9.0 KIP)

R RATIO -1.0

TEST TEMPERATURE 422 K (300 °F)



25 CYCLES
(FAILURE)

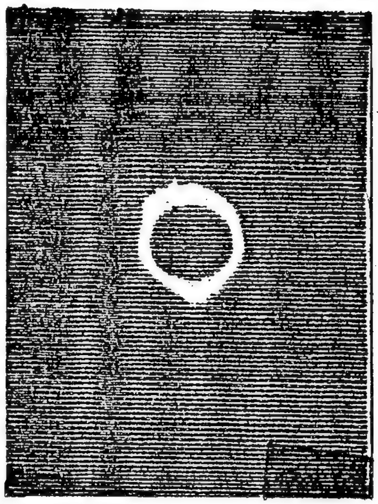
LAMINATE L1

SPECIMEN NO. L1-31-79

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

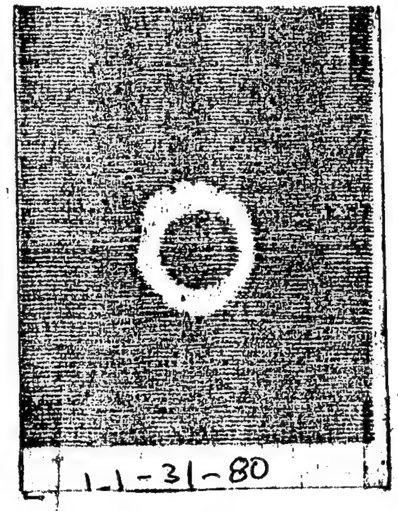
NO PRELOAD

AFTER PRELOAD

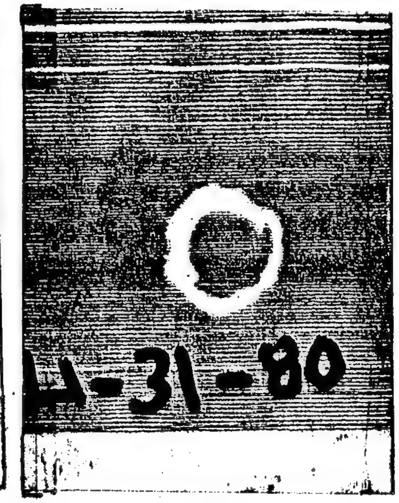
MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



10 CYCLES



10^6 CYCLES

CYCLIC LOAD 46.7kN (10.5 KIP)

R RATIO 0.05

TEST TEMPERATURE ROOM

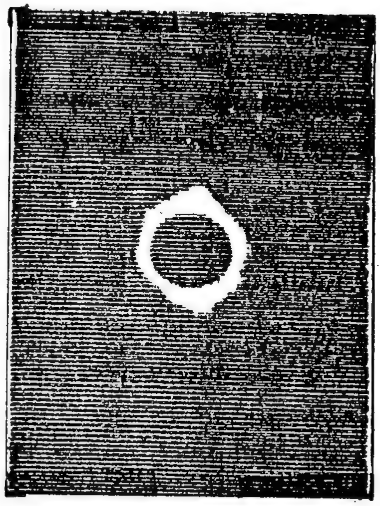
LAMINATE L1

SPECIMEN NO. L1-31-80

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

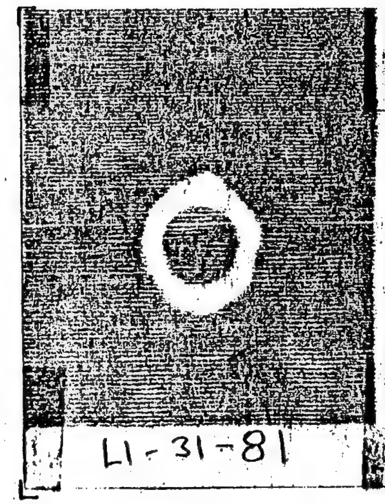
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE ROOM

______ CYCLES

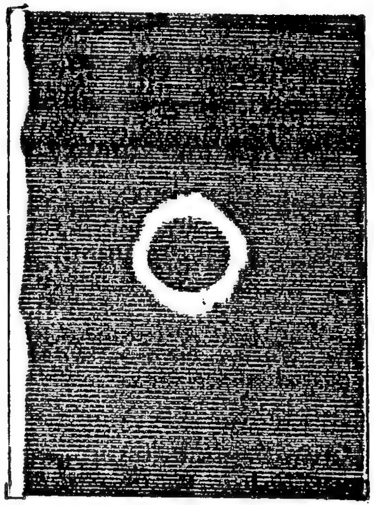
LAMINATE L1

SPECIMEN NO. L1-31-81

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

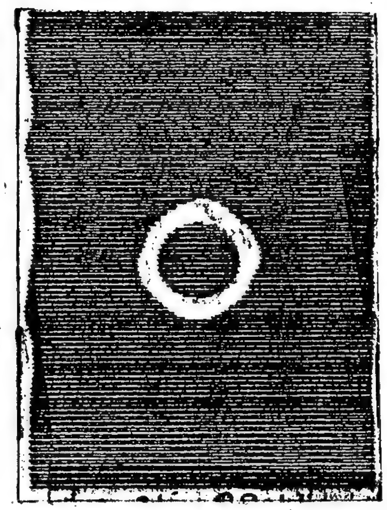
NO PRELOAD

AFTER PRELOAD

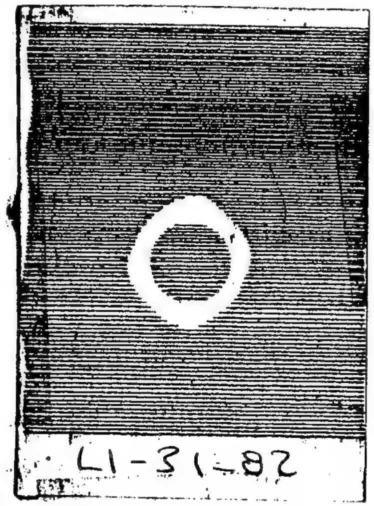
MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



10 CYCLES



10^3 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-82

DEFECT 5/8 FP HOLE

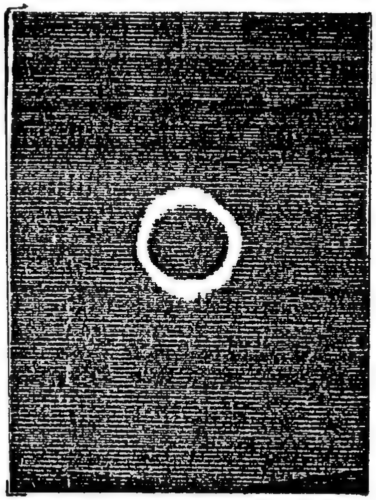
TEST TYPE CYCLIC

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F)

ULTRASONIC C-SCAN DATA



BEFORE TEST

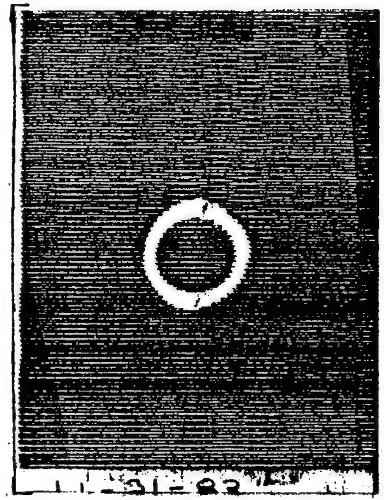
NO PRELOAD

AFTER PRELOAD

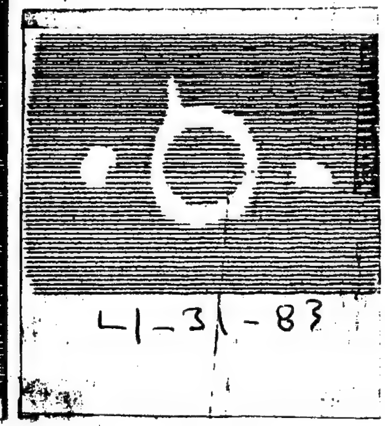
MAXIMUM LOAD –

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES



10^6 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-83

DEFECT 5/8 FP HOLE

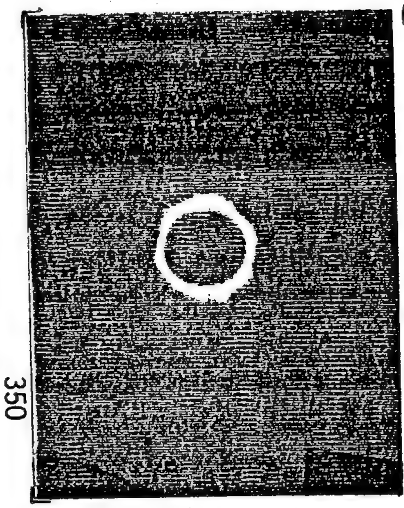
TEST TYPE CYCLIC

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 k (300 °F)

ULTRASONIC C-SCAN DATA



BEFORE TEST

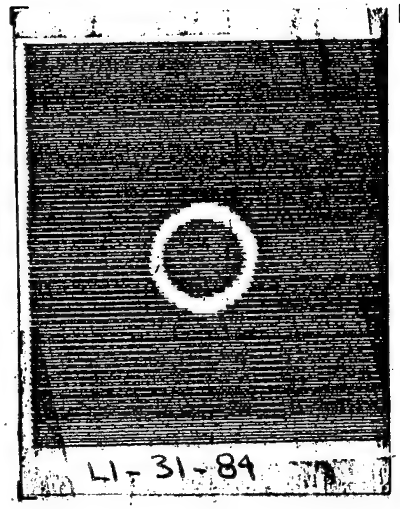
NO PRELOAD

AFTER PRELOAD

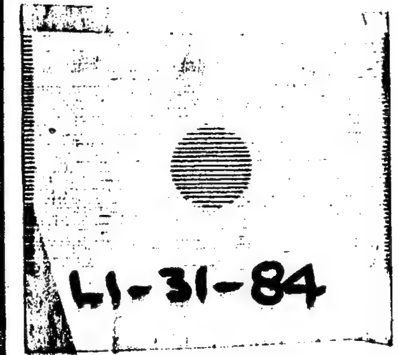
MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES



10^7 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-84

DEFECT 5/8 PP HOLE

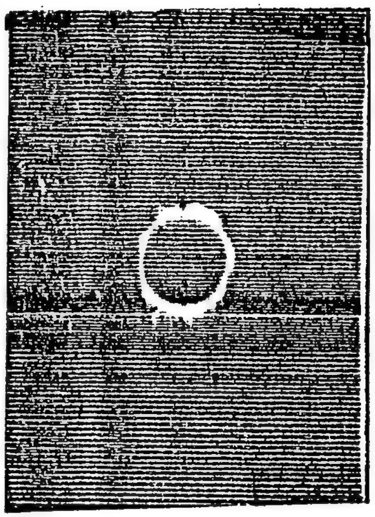
TEST TYPE CYCLIC

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300 °F)

ULTRASONIC C-SCAN DATA



BEFORE TEST

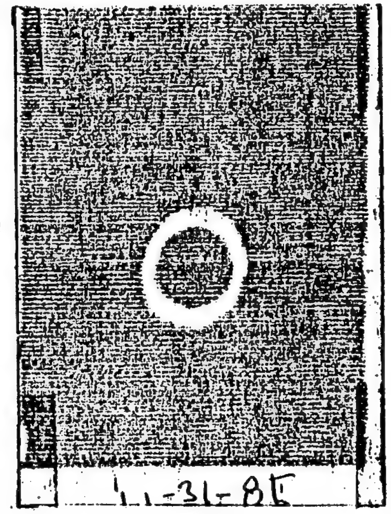
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



10 CYCLES

CYCLIC LOAD 40.0 kN (9.0 KIP)

R RATIO -1.0

TEST TEMPERATURE ROOM

CYCLES

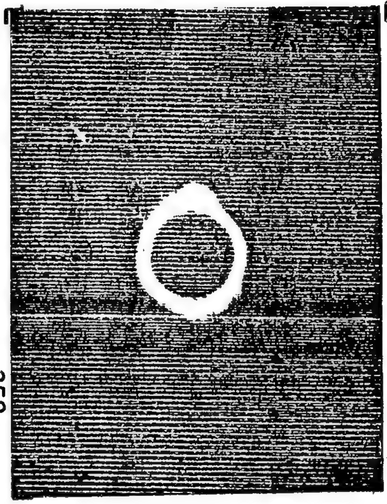
LAMINATE L1

SPECIMEN NO. L1-31-85

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

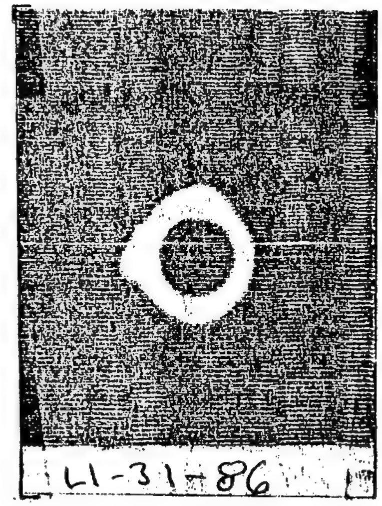
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD ______

NOT CONDITIONED

AFTER MOISTURE CONDITIONING



100 CYCLES

______ CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-86

DEFECT 5/8 FP HOLE

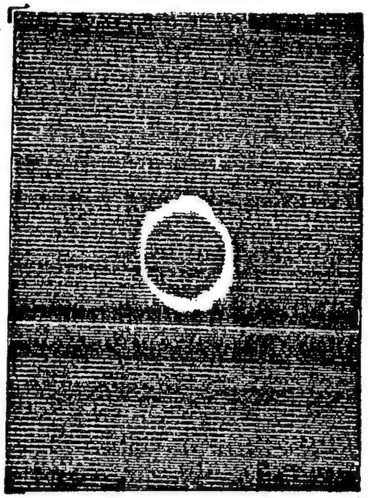
TEST TYPE CYCLIC

CYCLIC LOAD 37.8 kN (8.5 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM

ULTRASONIC C-SCAN DATA



BEFORE TEST

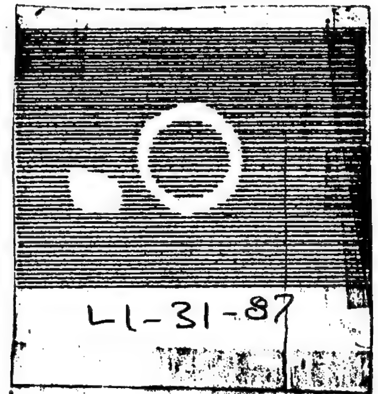
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

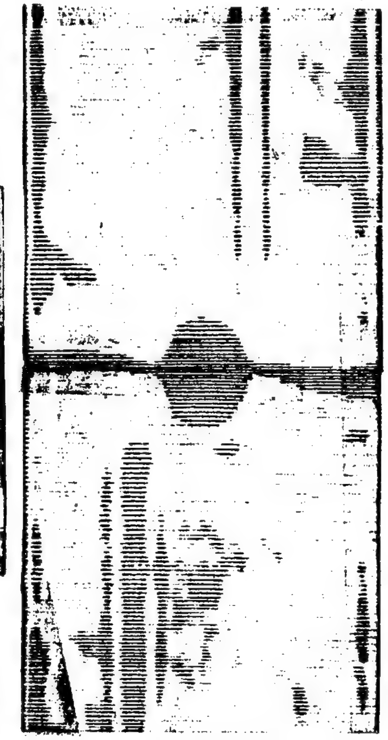


10 CYCLES

CYCLIC LOAD 40.0 kN (9.0 kip)

R RATIO -1.0

TEST TEMPERATURE 422 K (300°F)



117 CYCLES
(FAILURE)

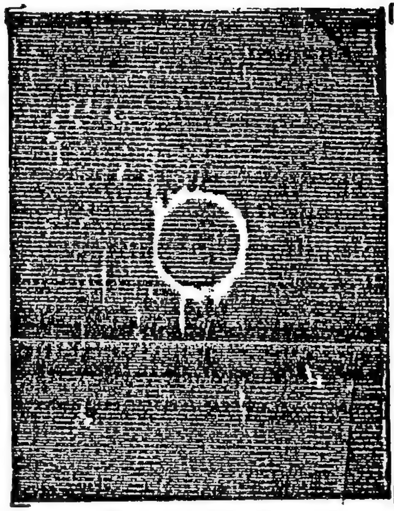
LAMINATE L1

SPECIMEN NO. L1-31-87

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

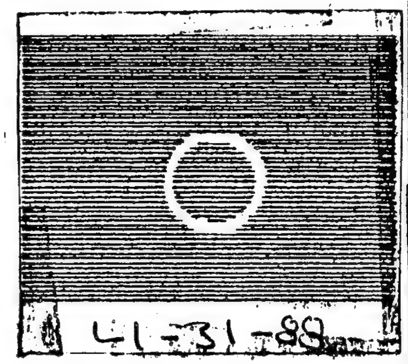
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

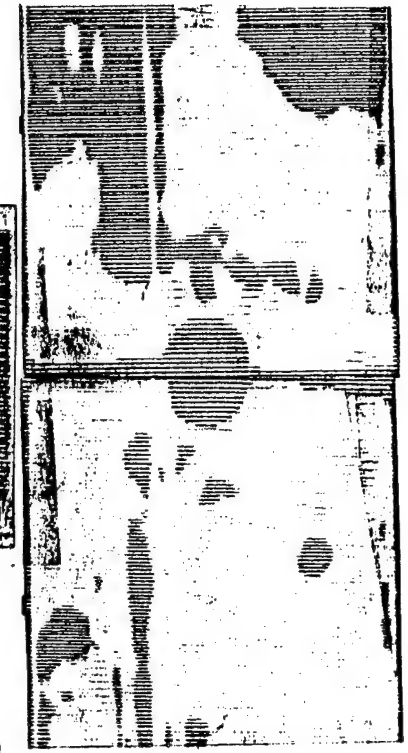


100 CYCLES

CYCLIC LOAD 40.0 kN (9.0 kip)

R RATIO −1.0

TEST TEMPERATURE 422K (300°F)



1700 CYCLES
(FAILURE)

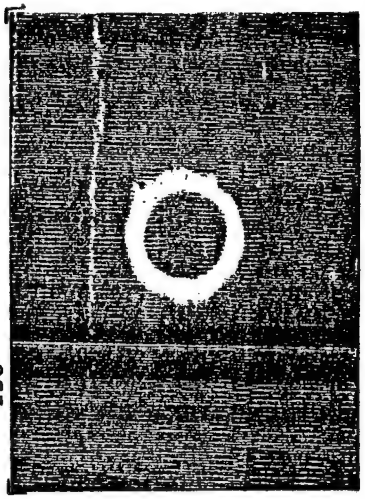
LAMINATE L1

SPECIMEN NO. L1-31-88

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA



BEFORE TEST

NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD ________

NOT CONDITIONED

AFTER MOISTURE CONDITIONING

________ CYCLES
<1 TO FAIL

________ CYCLES

CYCLIC LOAD ________

R RATIO ________

TEST TEMPERATURE ________

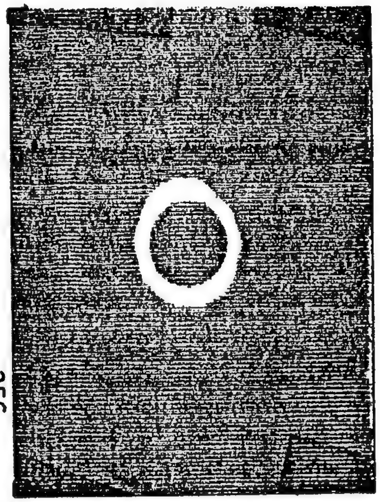
LAMINATE L1

SPECIMEN NO. L1-31-89

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

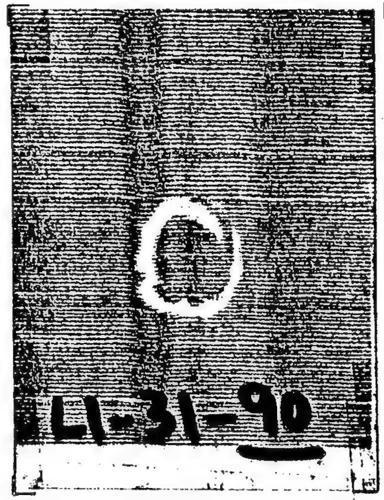


BEFORE TEST

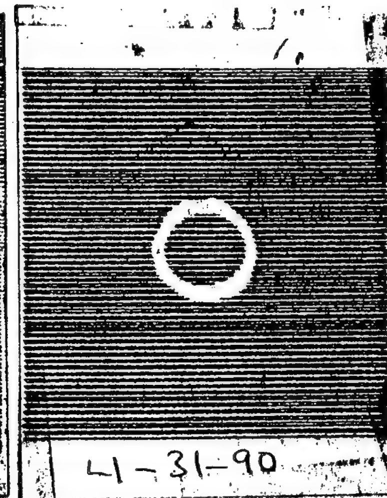
NO PRELOAD

AFTER PRELOAD

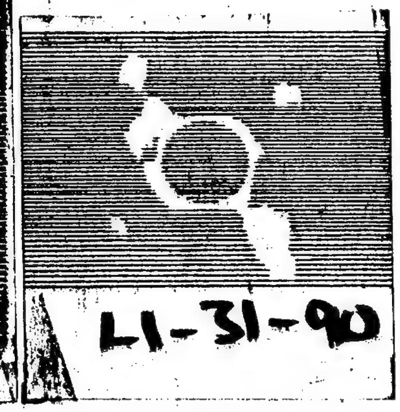
MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING



100 CYCLES



10^7 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE ROOM

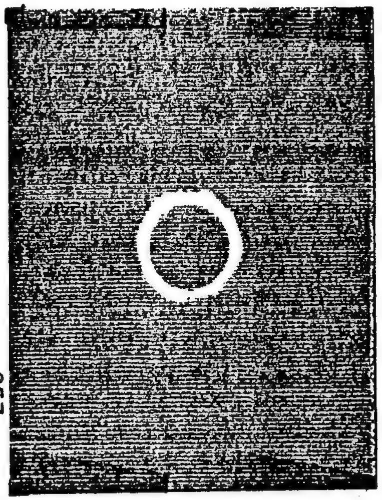
LAMINATE L1

SPECIMEN NO. L1-31-90

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

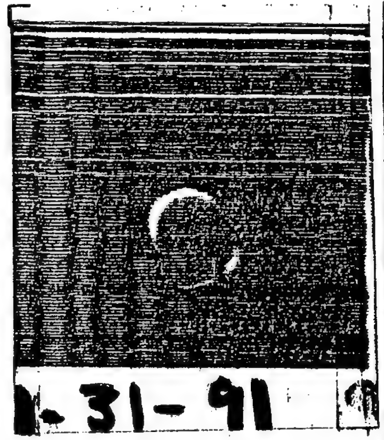


BEFORE TEST

NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING

10 CYCLES

10^3 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-91

DEFECT 5/8 FP HOLE

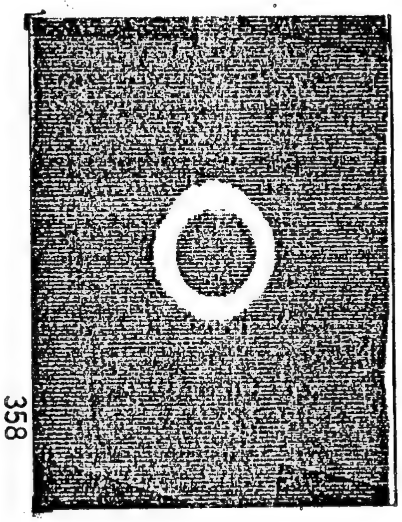
TEST TYPE CYCLIC

CYCLIC LOAD 46.7kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422K (300°F)

ULTRASONIC C-SCAN DATA

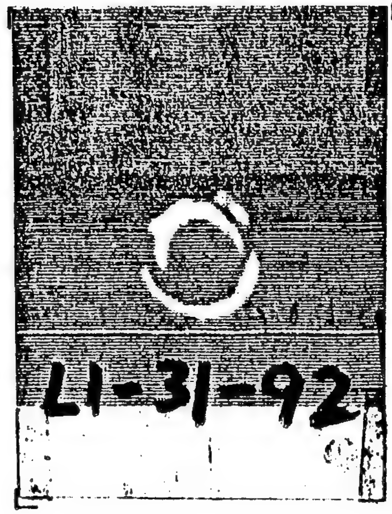


BEFORE TEST

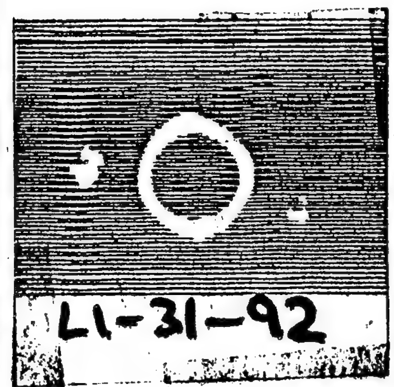
NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD ________



AFTER MOISTURE CONDITIONING



100 CYCLES

10^6 CYCLES

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300°F

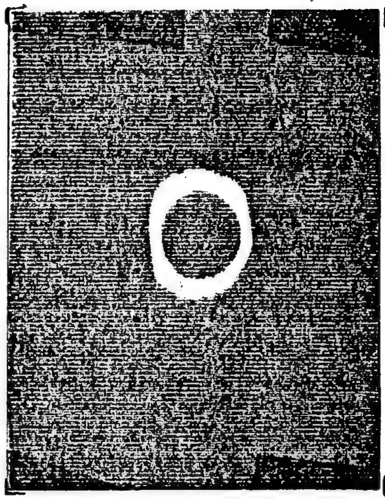
LAMINATE L1

SPECIMEN NO. L1-31-92

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

ULTRASONIC C-SCAN DATA

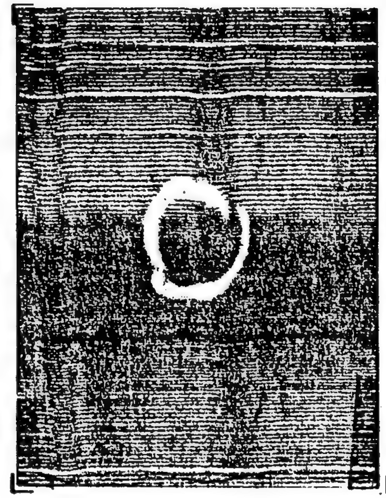


BEFORE TEST

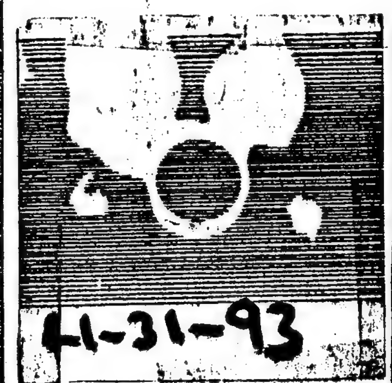
NO PRELOAD

AFTER PRELOAD

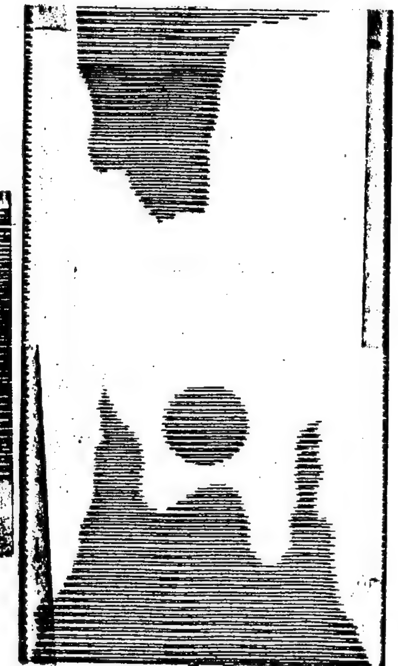
MAXIMUM LOAD -



AFTER MOISTURE CONDITIONING



100 CYCLES



10^7 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-93

DEFECT 5/8 FD HOLE

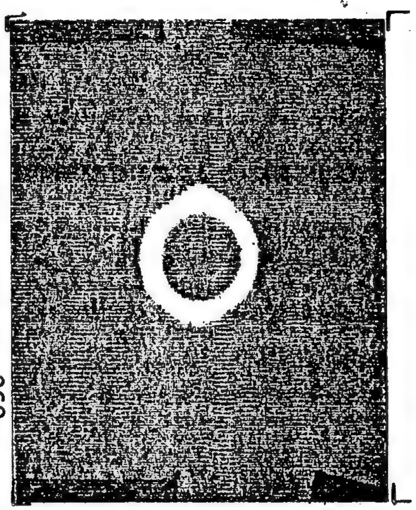
TEST TYPE CYCLIC

CYCLIC LOAD 46.7 kN (10.5 kip)

R RATIO 0.05

TEST TEMPERATURE 422 K (300 °F)

ULTRASONIC C-SCAN DATA



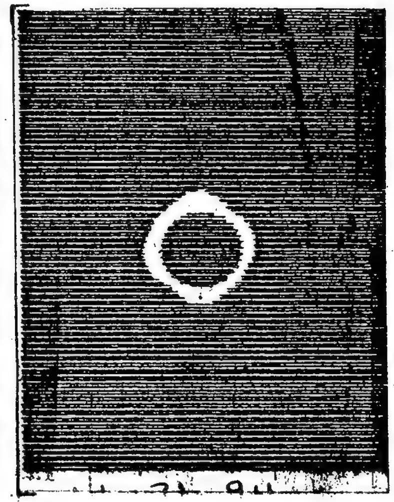
BEFORE TEST

NO PRELOAD

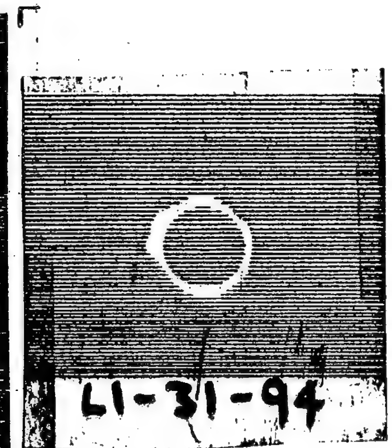
AFTER PRELOAD

MAXIMUM LOAD —

AFTER MOISTURE CONDITIONING



10 CYCLES



10^3 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-94

DEFECT 5/8 FP HOLE

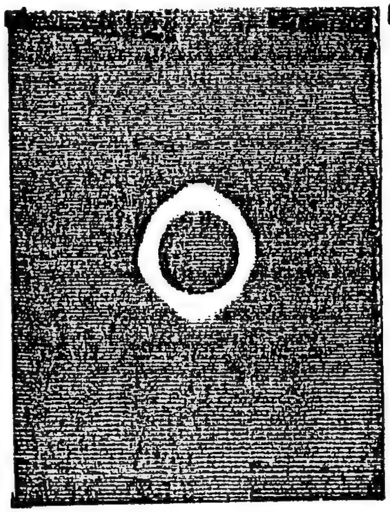
TEST TYPE CYCLIC

CYCLIC LOAD 40.0 kN (9.0 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM

ULTRASONIC C-SCAN DATA

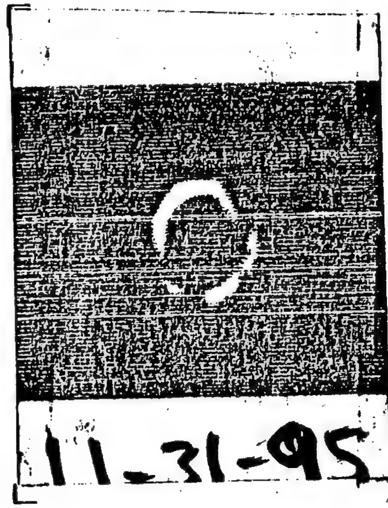


BEFORE TEST

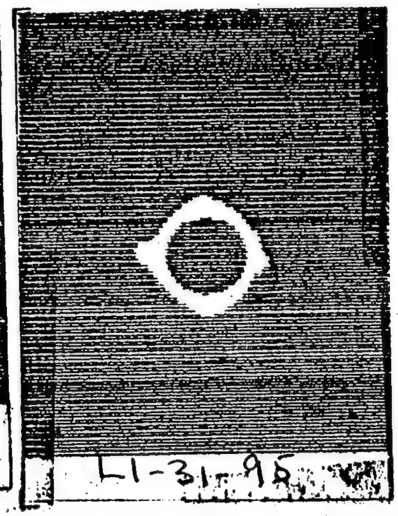
NO PRELOAD

AFTER PRELOAD

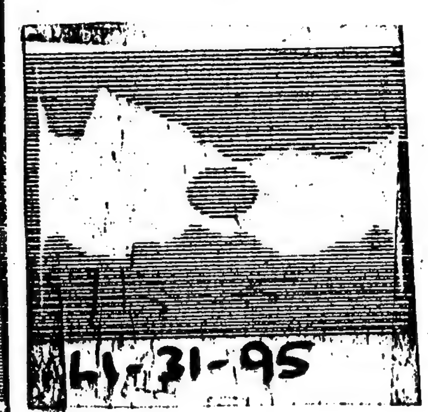
MAXIMUM LOAD –



AFTER MOISTURE CONDITIONING



100 CYCLES



450 CYCLES
(FAILURE)

LAMINATE L1

SPECIMEN NO. L1-31-95

DEFECT 5/8 FP HOLE

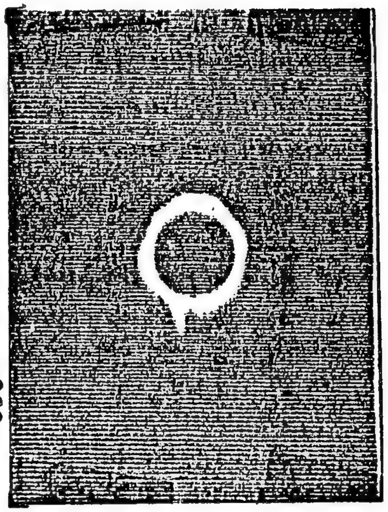
TEST TYPE CYCLIC

CYCLIC LOAD 40.0 kN (9.0 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM

ULTRASONIC C-SCAN DATA

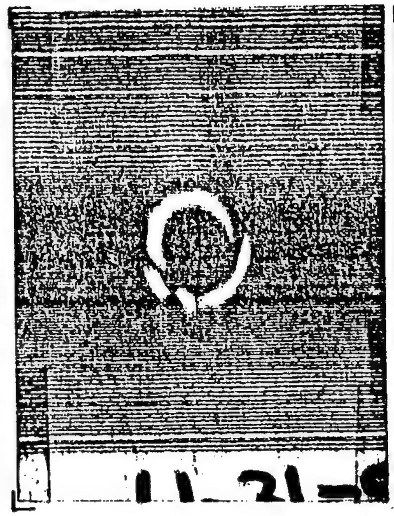


BEFORE TEST

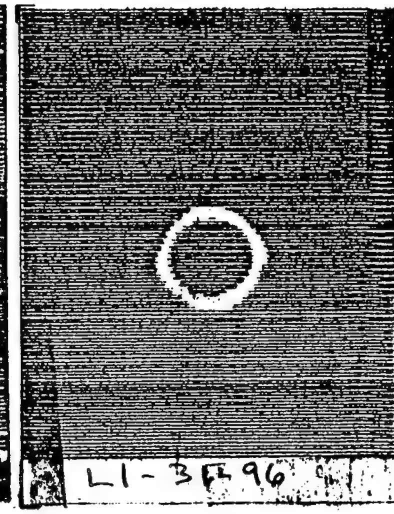
NO PRELOAD

AFTER PRELOAD

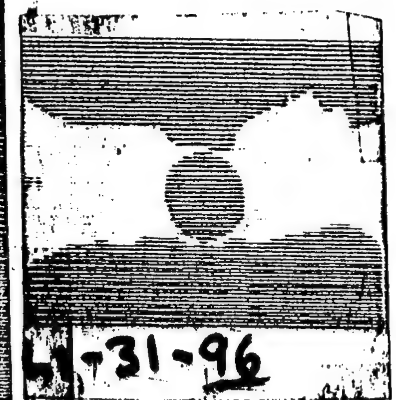
MAXIMUM LOAD –



AFTER MOISTURE CONDITIONING



100 CYCLES



1350 CYCLES (FAILURE)

CYCLIC LOAD 37.8 kN (8.5 kip)

R RATIO -1.0

TEST TEMPERATURE ROOM

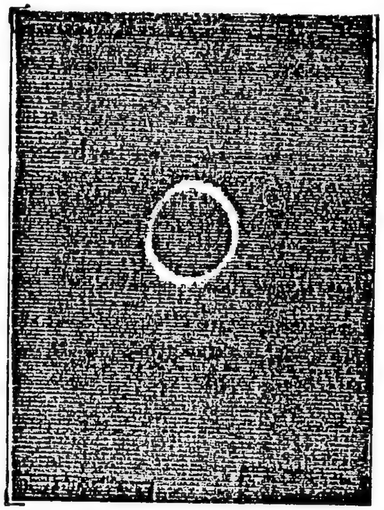
LAMINATE L1

SPECIMEN NO. L1-31-96

DEFECT 5/8 FP HOLE

TEST TYPE CYCLIC

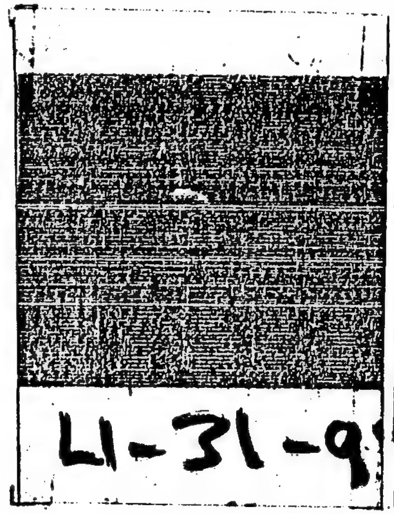
ULTRASONIC C-SCAN DATA



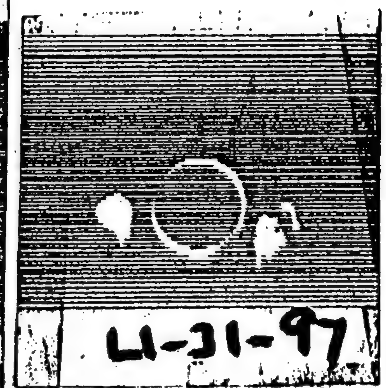
BEFORE TEST

NO PRELOAD

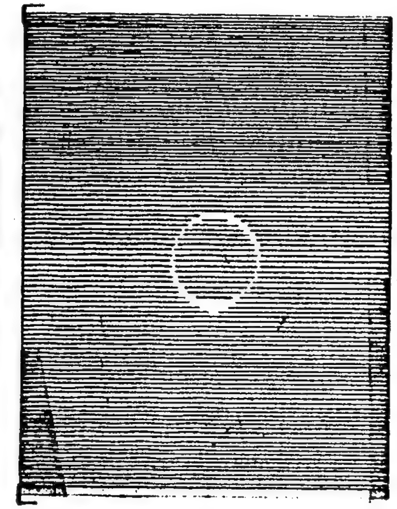
AFTER PRELOAD



AFTER MOISTURE CONDITIONING



10 CYCLES



10^3 CYCLES

MAXIMUM LOAD —

LAMINATE L1

SPECIMEN NO. L1-31-97

DEFECT 5/8 FP HOLE

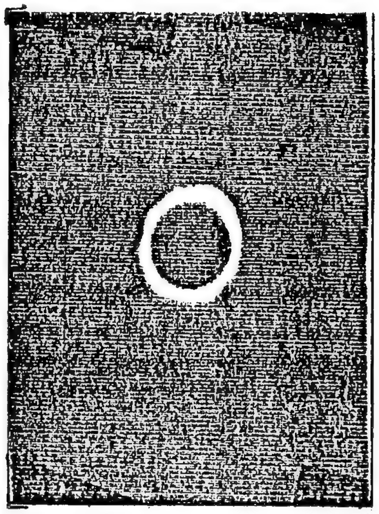
TEST TYPE CYCLIC

CYCLIC LOAD 13.3 kN (3.0 kip)

R RATIO −1.0

TEST TEMPERATURE 422 K (300°F)

ULTRASONIC C-SCAN DATA

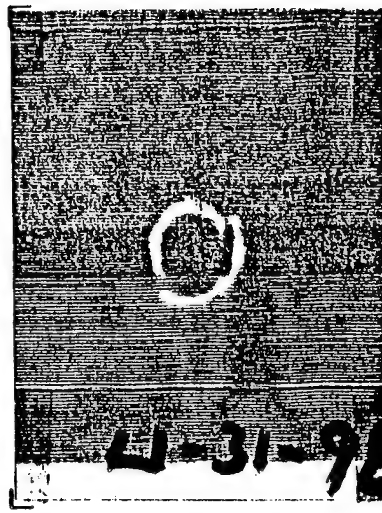


BEFORE TEST

NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING

100 CYCLES

_____ CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-98

DEFECT 5/8 FP HOLE

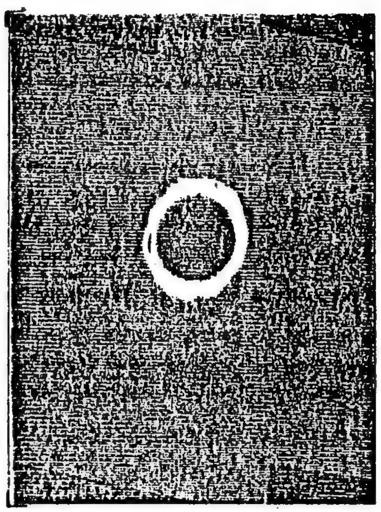
TEST TYPE CYCLIC

CYCLIC LOAD 13.3kN(3.0 kip)

R RATIO -1.0

TEST TEMPERATURE 422k(300°F)

ULTRASONIC C-SCAN DATA

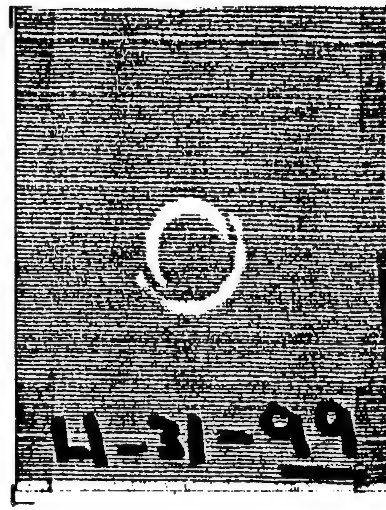


BEFORE TEST

NO PRELOAD

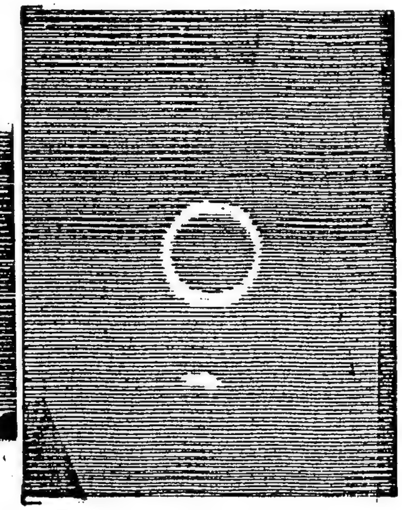
AFTER PRELOAD

MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING

100 CYCLES



10^7 CYCLES

LAMINATE L1

SPECIMEN NO. L1-31-99

DEFECT 5/8 FP HOLE

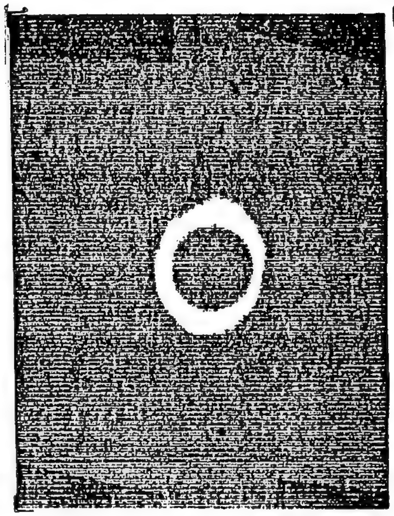
TEST TYPE CYCLIC

CYCLIC LOAD 13.3 kN (3.0 kip)

R RATIO −1.0

TEST TEMPERATURE 422 K (300°F)

ULTRASONIC C-SCAN DATA

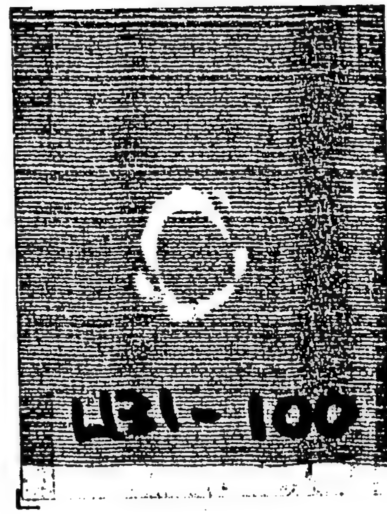


BEFORE TEST

NO PRELOAD

AFTER PRELOAD

MAXIMUM LOAD —



AFTER MOISTURE CONDITIONING

NO CYCLING

____ CYCLES

____ CYCLES

CYCLIC LOAD ____

R RATIO ____

TEST TEMPERATURE ____

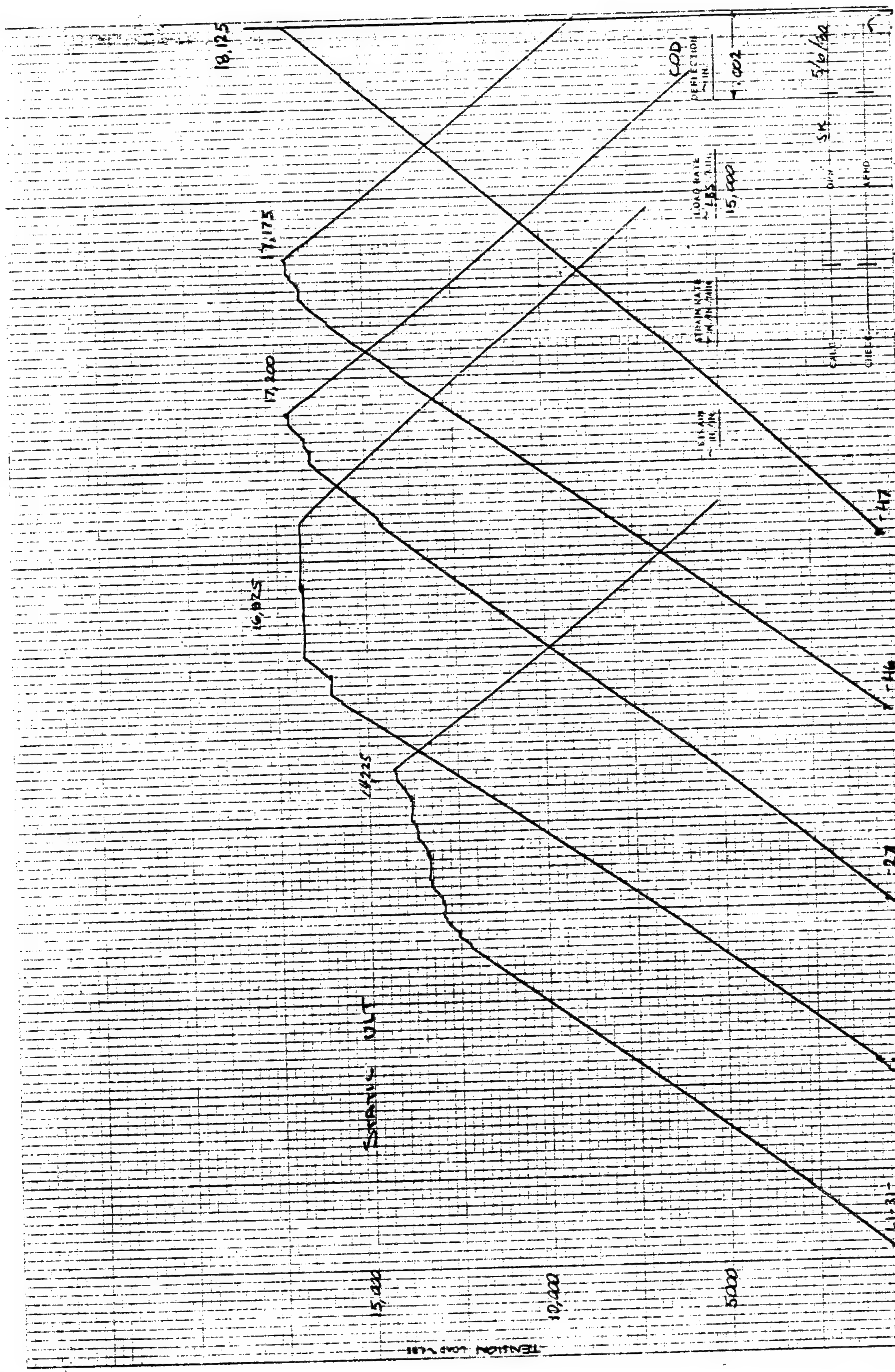
LAMINATE L1

SPECIMEN NO. L1-31-100

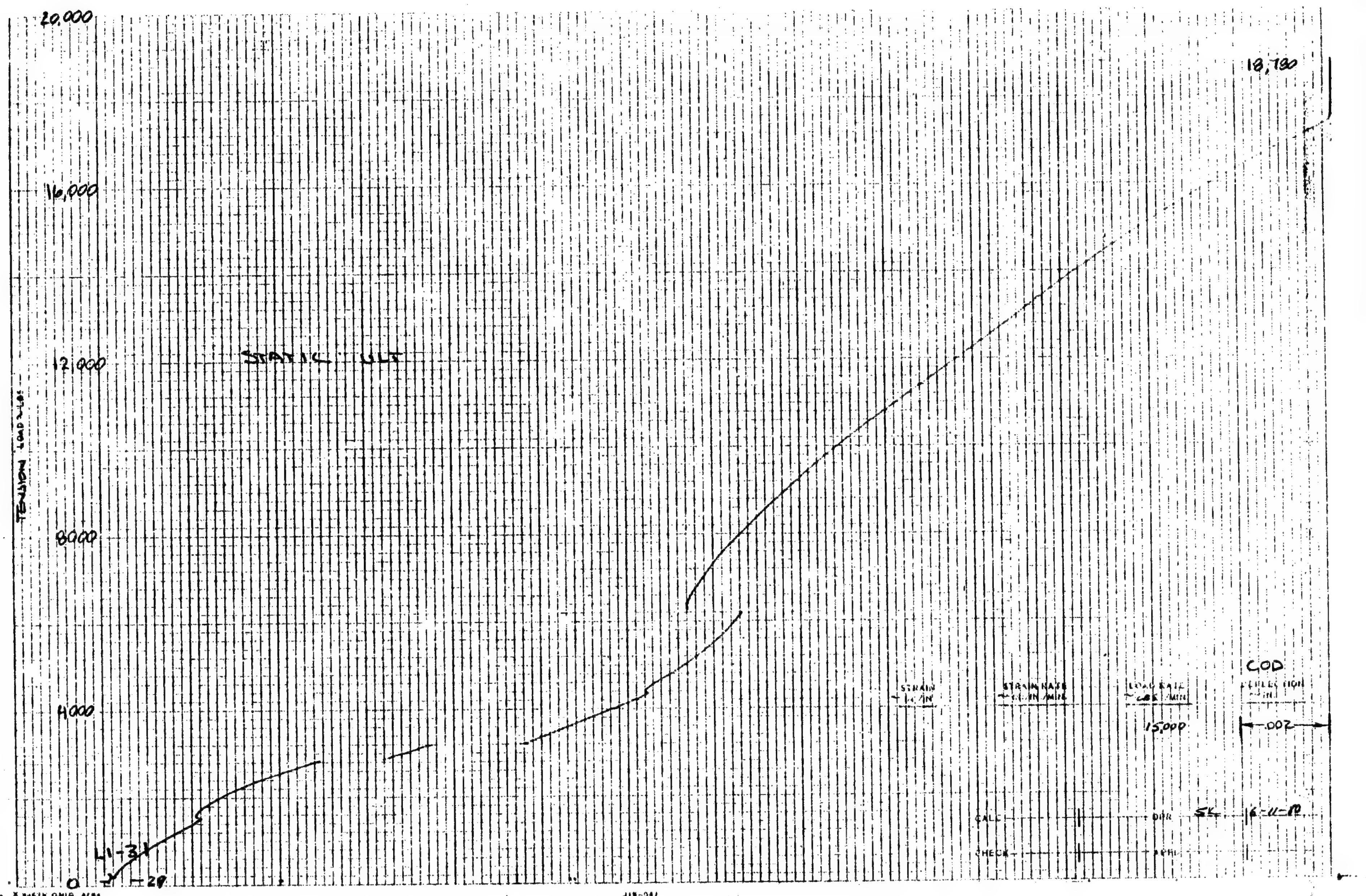
DEFECT 5/8 FD HOLE

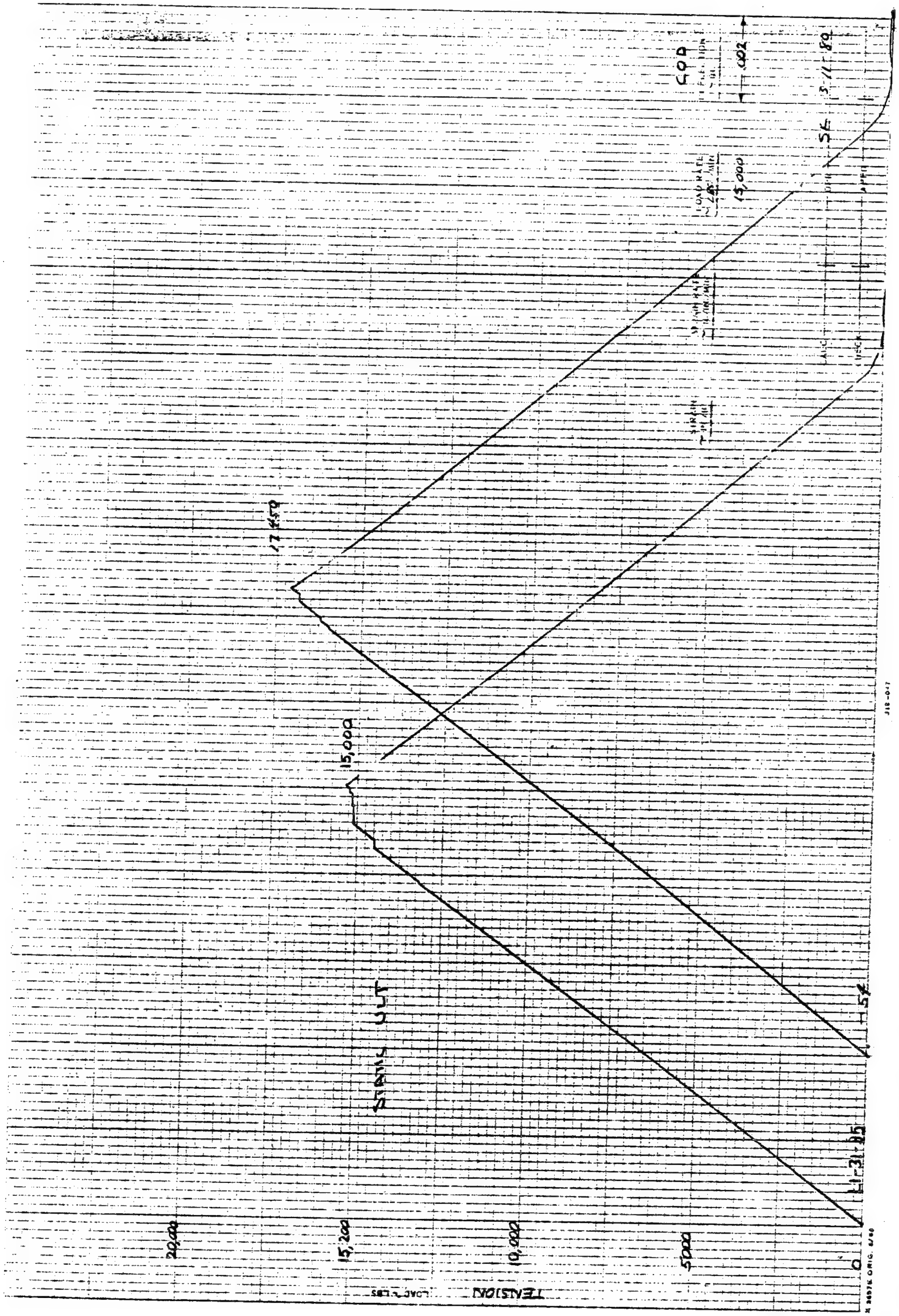
TEST TYPE COMPRESSION STATIC

SPECIMEN NUMBER	MAX./MIN. LOAD (LBS)	CRACK OPENING DISPLACEMENT GAGE TRACE AMPLITUDE CHART (INCHES)							
		SCALE (IN/IN)	NUMBER OF LOAD CYCLES						
			10	100	1000	10^4	10^5	10^6	10^7
L1-31-25	10,500/525	.002	3.07	3.10	3.18	--	--	--	--
-26	10,500/525	.002	2.90	2.96	3.00	2.95	2.97	3.00	--
-27	10,500/525	.002	--	2.93	2.90	3.00	3.00	2.98	3.20
-28	10,500/525	.002	3.15	3.22	3.40	--	--	--	--
-29	10,500/525	.002	3.25	3.61	3.67	4.40	4.60	4.80	--
-30	10,500/525	.002	--	3.46	--	--	--	--	--
-31	9,000/-9,000	.002	4.82	4.90	--	--	--	--	--
-32	9,000/-9,000	.002	5.55	5.42	--	--	--	--	--
-33	8,500/-8,500	.002	--	4.97	--	--	--	--	--
		.004	--	--	2.17	--	--	--	--
-34	6,000/-6,000	.002	--	--	--	--	--	--	--
-35	10,500/525	.002	3.19	3.30	3.30	3.20	3.30	3.27	--
-36	10,500/525	.002	2.86	2.86	3.01	3.02	3.11	2.98	--
-37	10,500/525	.002	2.10	--	2.85	--	--	--	--
-38	10,500/525	.002	3.16	3.16	3.20	3.27	3.03	7.30	--
-39	10,500/525	.002	--	2.80	2.90	3.00	3.00	3.13	--
-40	9,000/-9,000	.002	5.35	5.82	6.30	8.18	--	--	--
-41	8,500/-8,500	.002	--	4.54	5.12	5.34	6.70	--	--
-42	9,000/-9,000	--	--	--	--	--	--	--	--
-43	9,000/-9,000	.002	--	4.80	5.40	--	--	--	--
-44	8,500/-8,500	.002	--	5.20	5.52	--	--	--	--
-45	6,500/-6,500	--	--	--	--	--	--	--	--
-46	10,500/525	.002	2.70	2.72	2.75	2.95	2.93	--	--
-47	10,500/525	.002	2.98	3.05	3.08	3.08	3.08	3.25	--
-48	10,500/525	.002	3.20	3.28	3.37	--	--	--	--
-49	10,500/525	.002	3.96	4.00	4.34	5.50	5.10	7.70	--
-50	9,000/-9,000	.002	5.45	--	--	--	--	--	--
		.004	--	3.00	--	--	--	--	--
-51	9,000/-9,000	.002	5.08	--	--	--	--	--	--
		.004	--	2.43	3.65	--	--	--	--
-52	5,000/-5,000	--	--	--	--	--	--	--	--
-53	3,000/-3,000	.002	1.70	1.35	1.32	1.50	1.50	1.52	--
-54	10,500/525	.002	--	3.00	2.95	2.95	2.98	2.99	3.00
-55	10,500/525	.002	3.17	3.04	3.06	--	--	--	--
-56	--	--	--	--	--	--	--	--	--
-57	8,500/-8,500	.002	--	5.50	5.52	6.78	--	--	--
-58	9,000/-9,000	--	--	--	--	--	--	--	--
-59	9,000/-9,000	--	--	--	--	--	--	--	--
-60	8,500/-8,500	--	--	--	--	--	--	--	--
-61	10,500/525	.002	2.69	2.62	2.68	2.70	2.73	2.75	--
-64	10,500/525	.002	3.62	3.85	--	--	--	--	--
-65	10,500/525	.002	3.66	3.66	3.66	3.72	3.72	3.80	--
-66	10,500/525	.002	3.65	3.70	3.72	--	--	--	--
-67	10,500/525	.002	3.75	3.80	3.80	3.85	3.87	3.96	--
-68	10,500/525	.004	1.90	--	--	--	--	--	--
		.002	--	4.15	4.40	--	--	--	--
L1-31 -69	10,500/525	.004	2.15	--	--	--	--	--	--

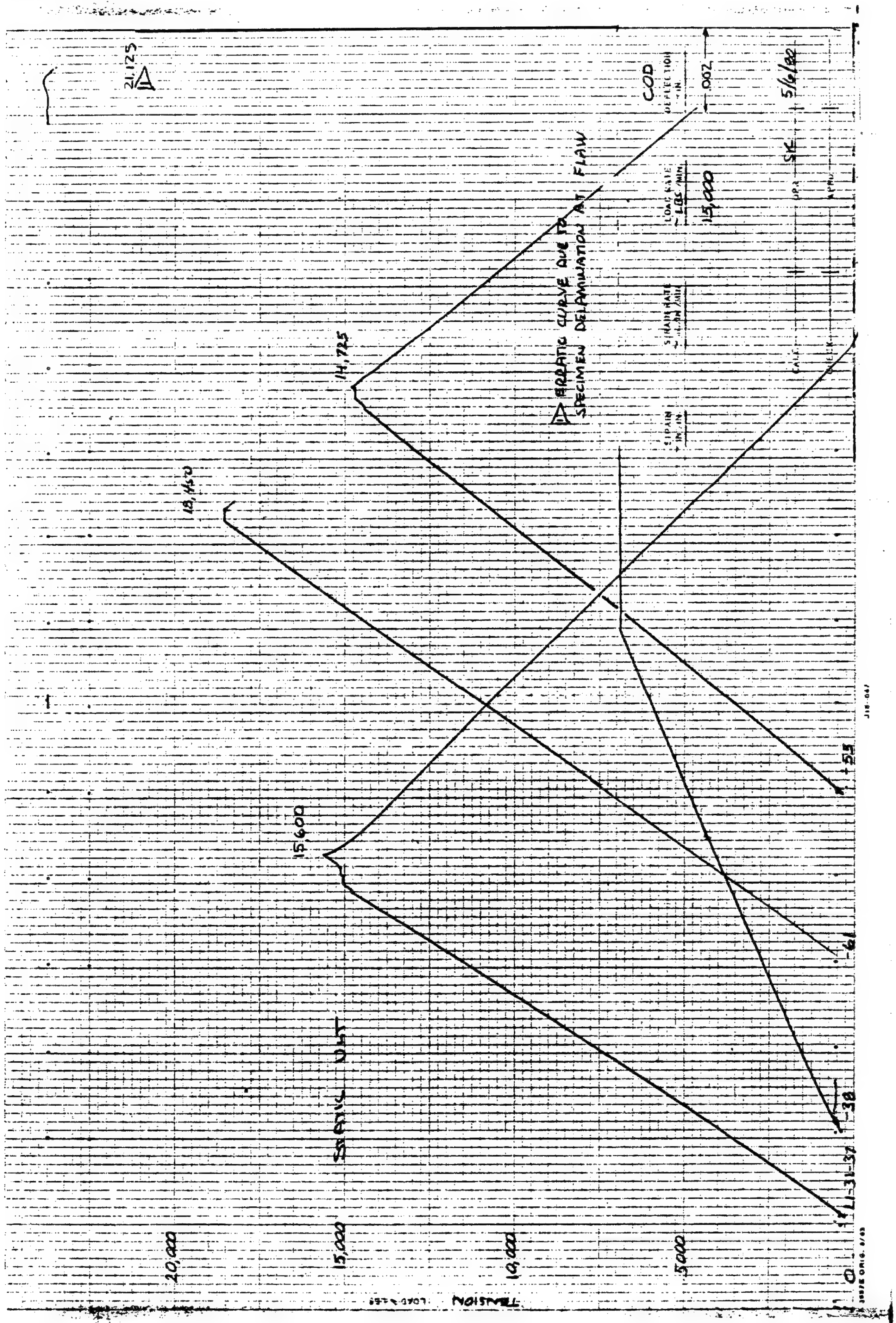


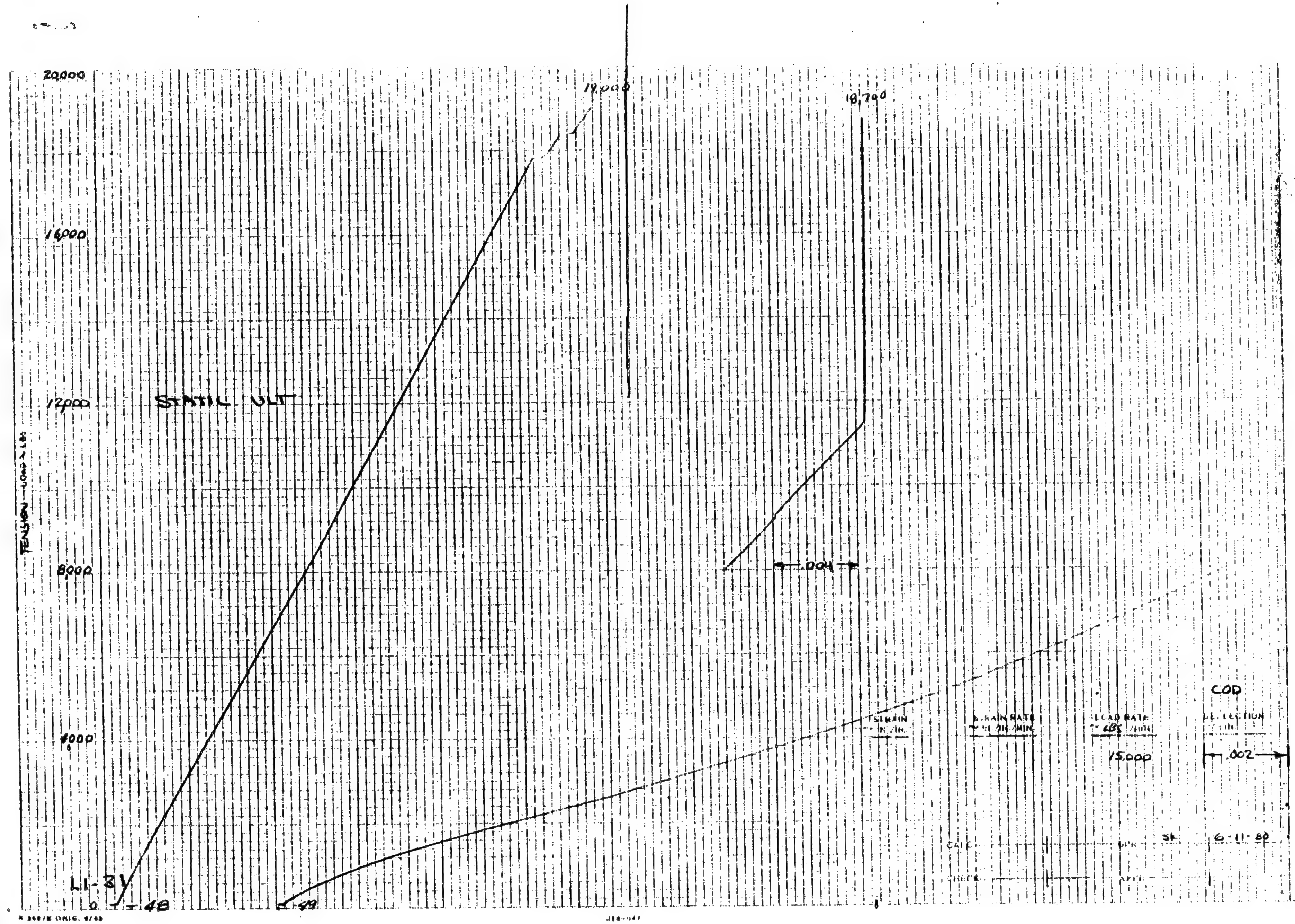
18,125
17,175
17,200
16,825
15,000
10,000
5000
0
TENSION LOAD LBS
STATIC ULT
-25
-26
-27
-46
-47
COD
DEFLECTION ~IN.
LOAD RATE ~LBS/MIN
15,000
STRAIN RATE ~IN/IN/MIN
STRAIN ~IN/IN
SK
CALC
CHECK
APPD


20,000
16,000
12,000
8000
4000
0
TENSION LOAD~LBS
STATIC ULT
18,780
41-31
28
STRAIN
STRAIN RATE
LOAD RATE
15,000
COD
DEFLECTION
.002
CALL
CHECK
DIR
SK
6-11-70
J18-047

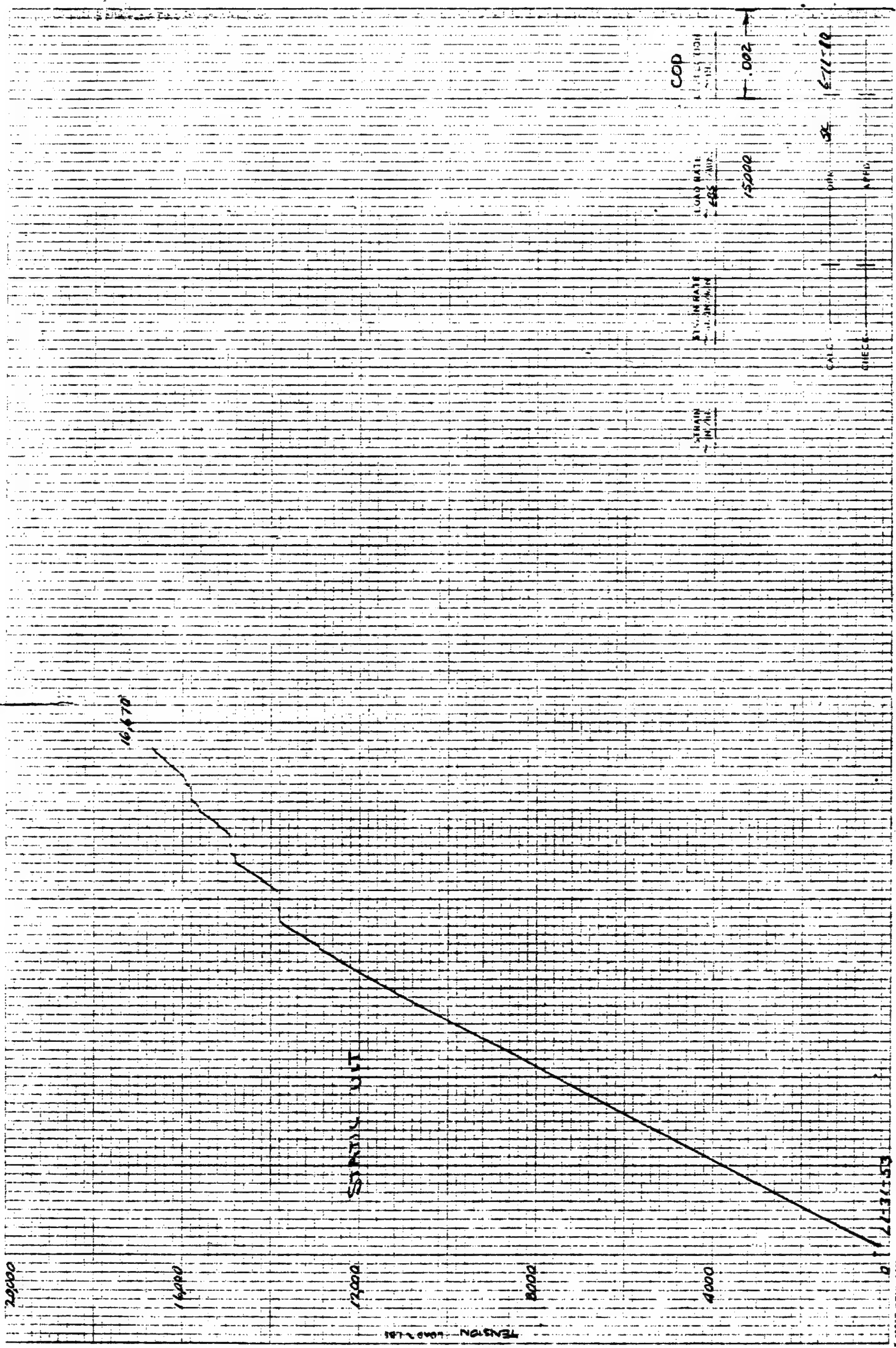


STATIC ULT
15,000
17,450
COD
.002
15,000
20,000
15,000
10,000
5000
0
TENSION

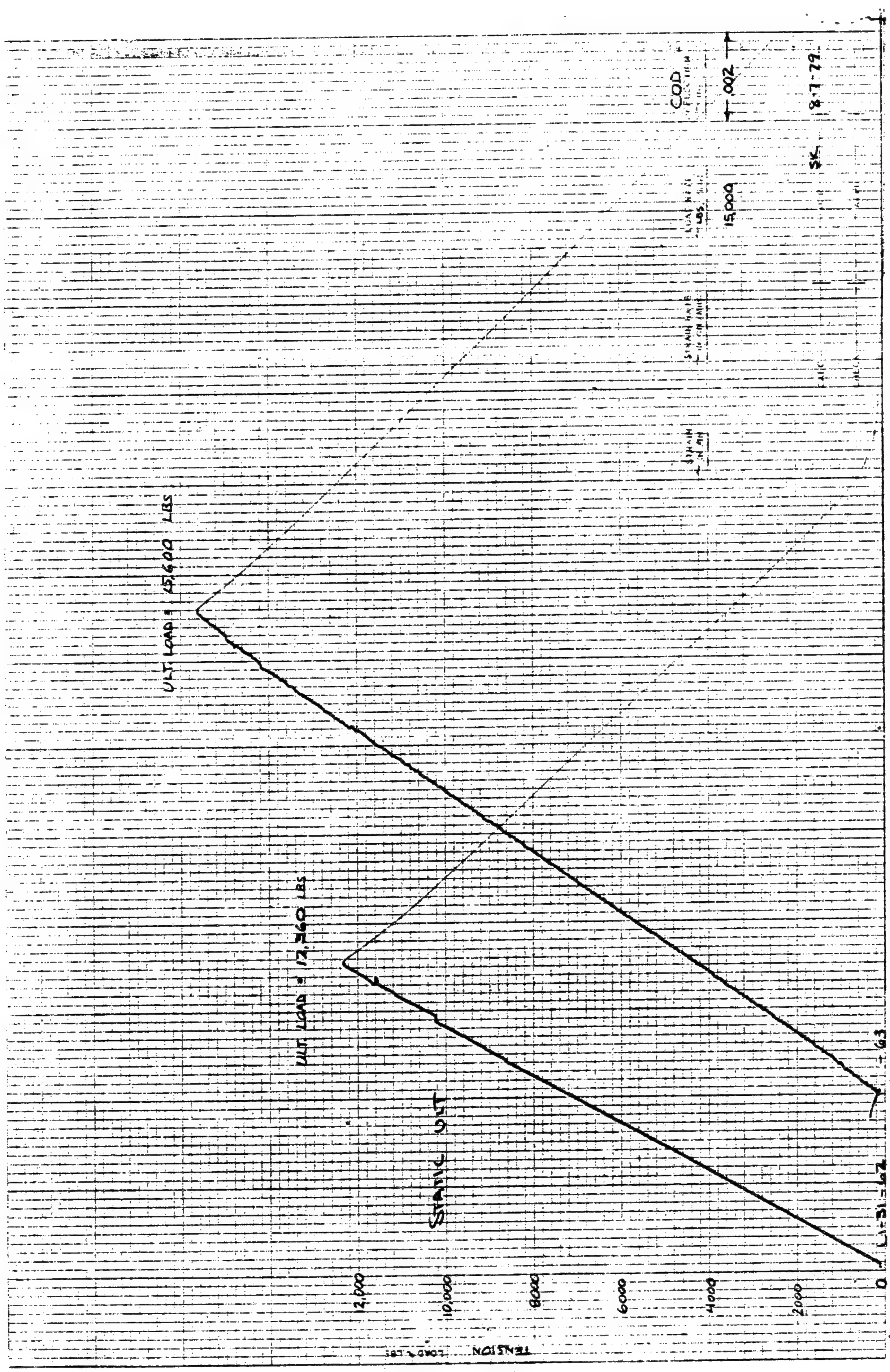

21,125
14,725
18,450
15,600
ERRATIC CURVE DUE TO SPECIMEN DELAMINATION AT FLAW
COD
DEFLECTION IN.
.002
LOAD RATE LBS/MIN
15,000
5/6/82
SK
STATIC ULT
LI-31-37
-38
-61
+55
20,000
15,000
10,000
5,000
0



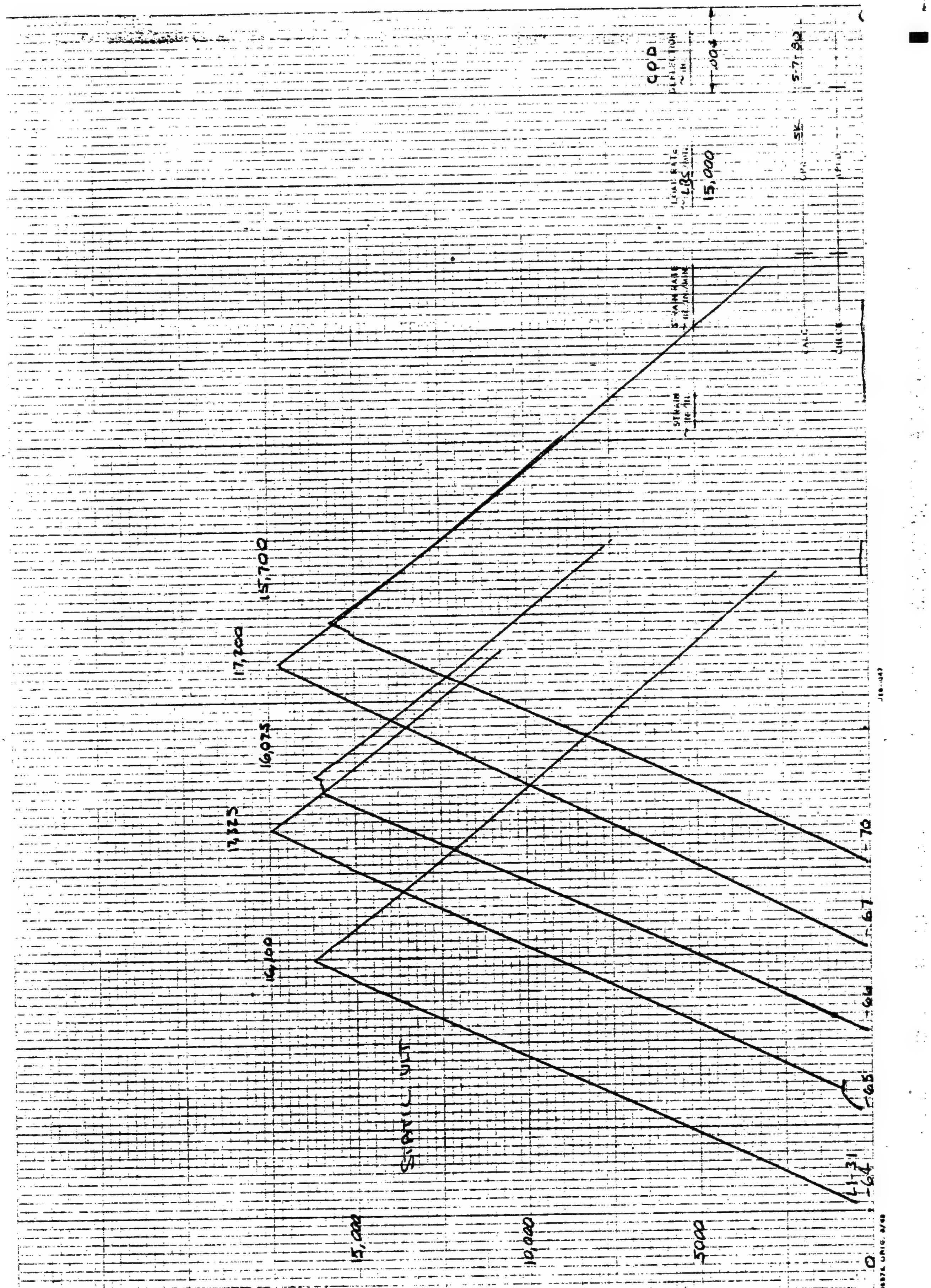
20,000
16,000
12,000
8000
4000
0
19,000
18,700
STATIC ULT
.004
LI-31
T-48
COD
15,000
.002
6-11-80
TENSION — LOAD ~ LBS

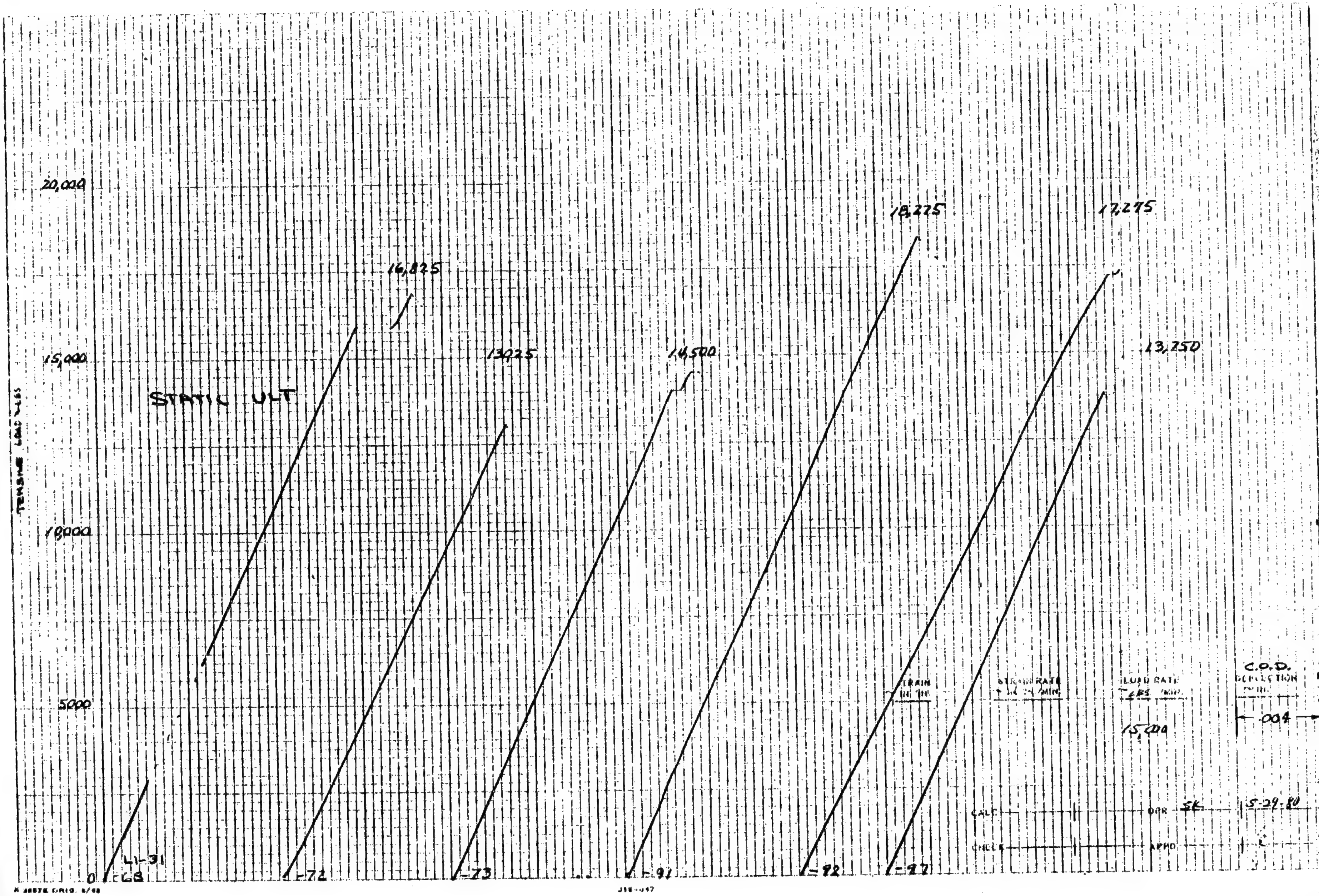


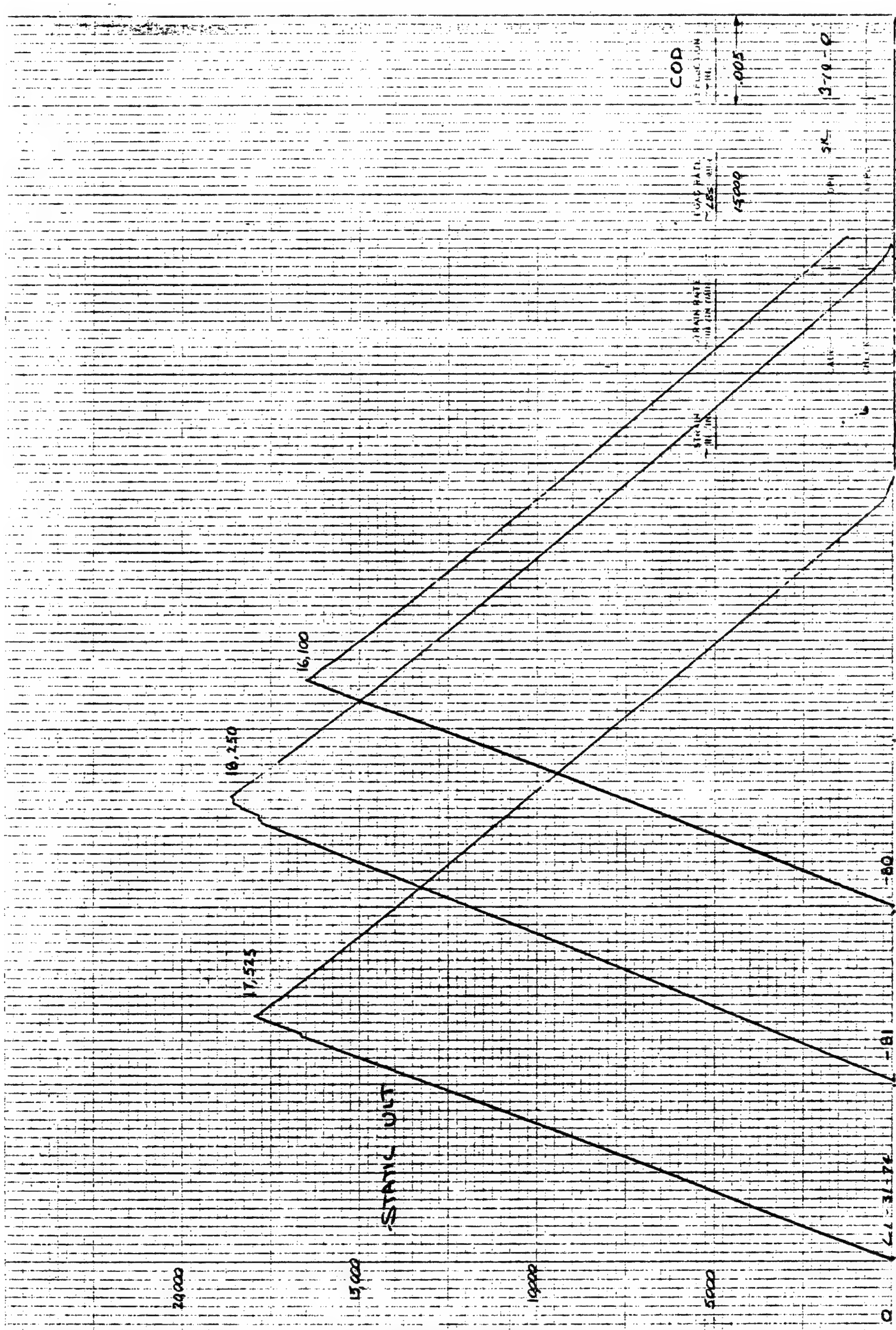
TENSION — LOAD ~ LBS
20,000
16,000
12,000
8000
4000
0
16,670
STATIC ULT
22-31-53
COD
.002
15000
CALC
CHECK
APPD
6-11-80

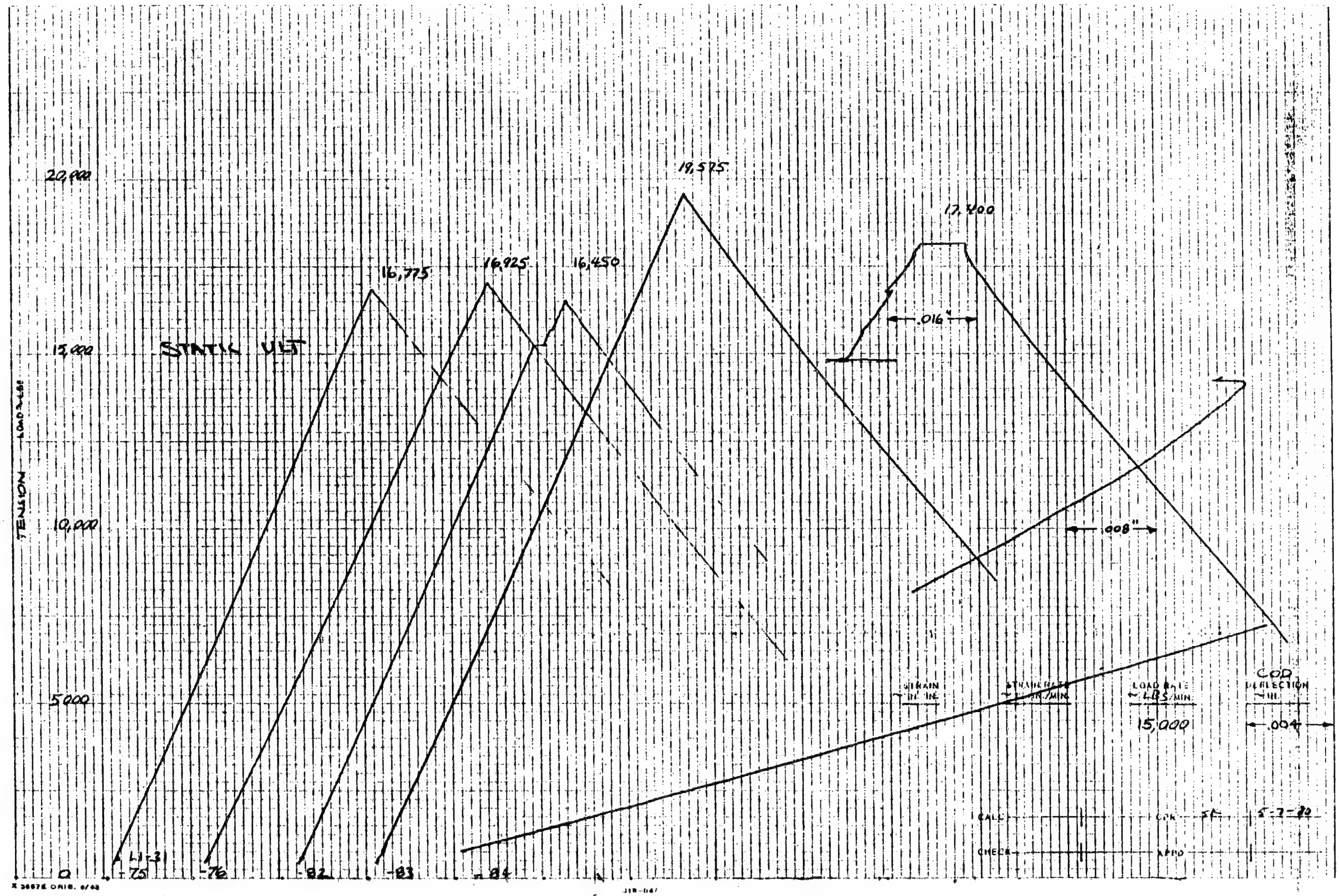


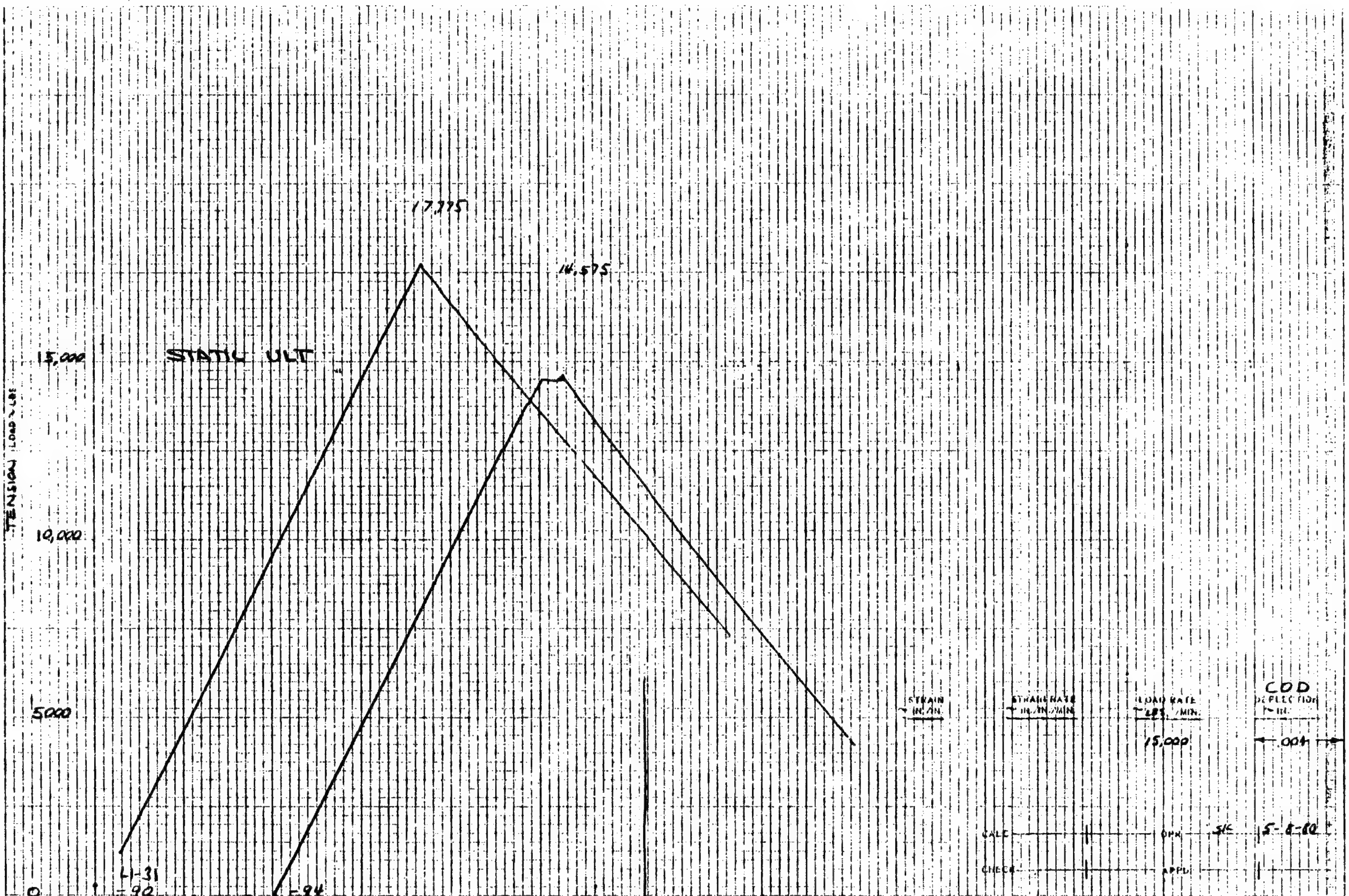
ULT LOAD = 15,600 LBS
ULT LOAD = 12,360 LBS
STATIC ULT
L1-31-62
63
COD
.002
15,000
SK
8-7-79
0
2000
4000
6000
8000
10,000
12,000
TENSION

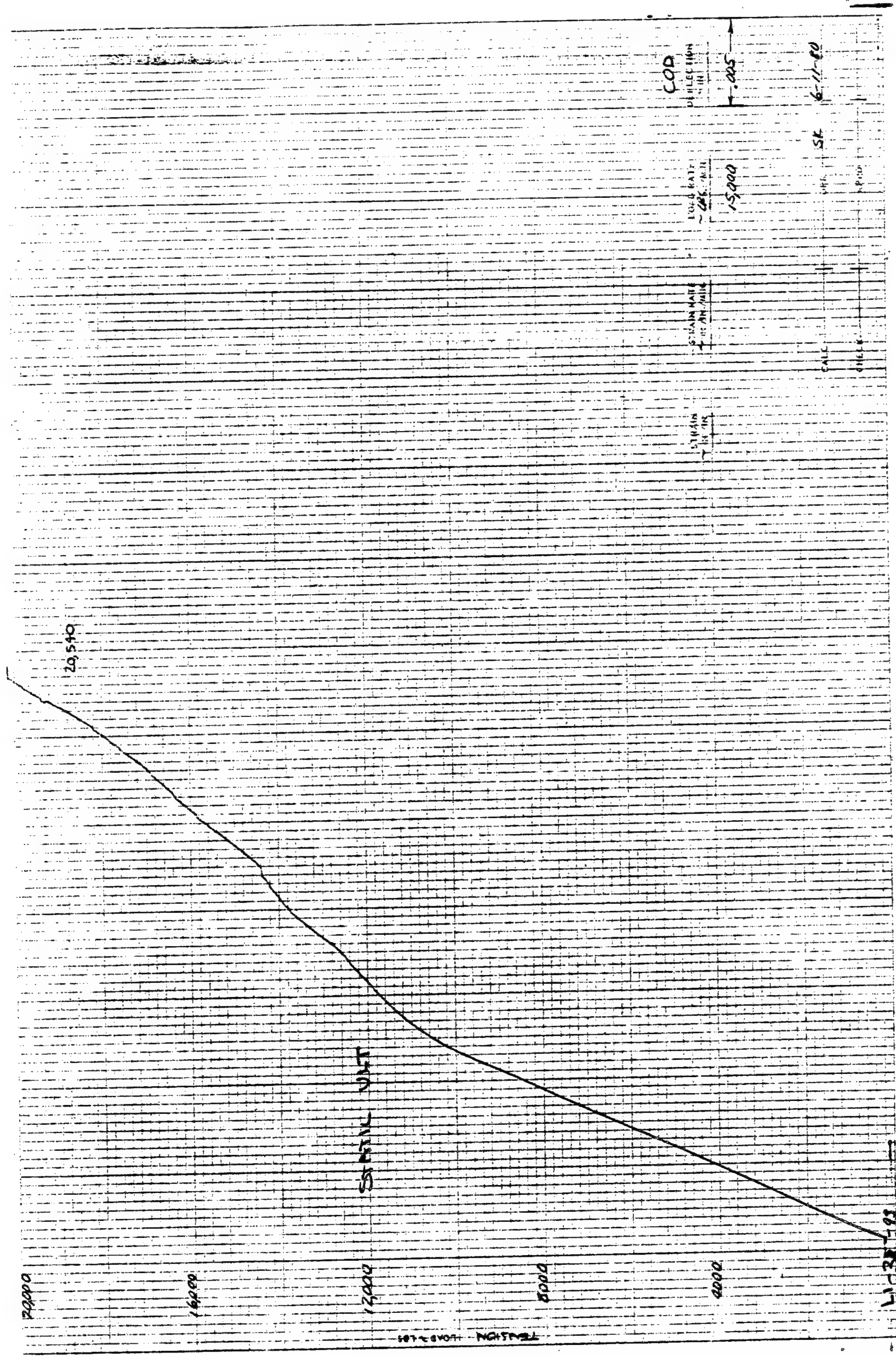

COD DEFLECTION ~ IN.
.004
LOAD RATE ~ LBS/MIN
15,000
STRAIN RATE
STRAIN
5-7-82
SK
TENSION
LOAD ~ LBS
15,000
10,000
5000
0
SPLIT ULT
16,100
17,325
16,075
17,200
15,700
L-64
L-65
L-66
L-67
L-70

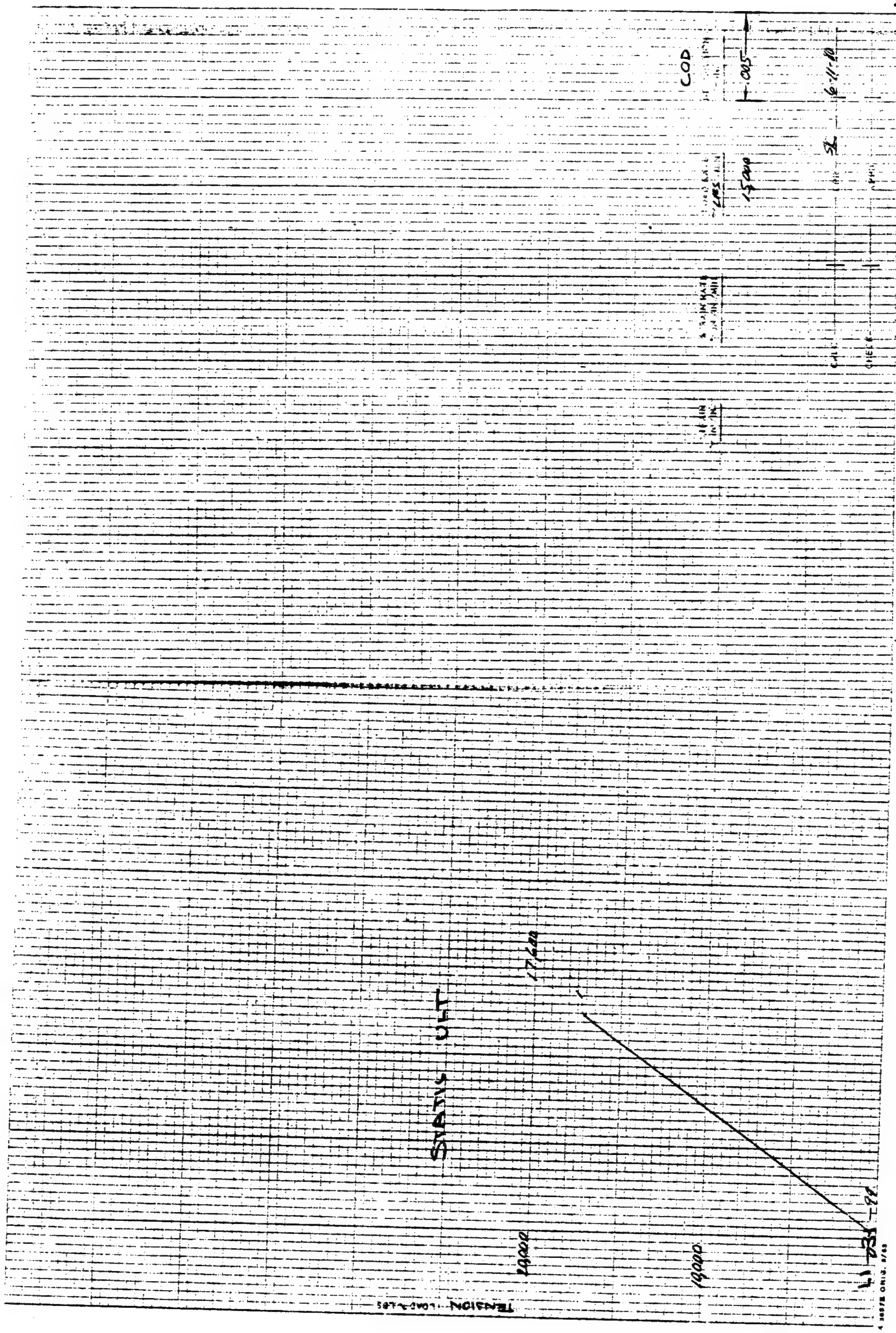

TENSILE LOAD LBS
20,000
15,000
10000
5000
0
STATIC ULT
16,825
13,025
14,500
18,275
17,275
13,250
41-31
-68
-72
-73
-91
-92
-97
C.O.D. DEFLECTION IN.
.004
LOAD RATE LBS/MIN.
15,000
OPR SK
5-29-80
CALC
CHECK
APPD


STATIC ULT
17,525
18,250
16,100
TENSION
20,000
15,000
10,000
5000
0
COD
.005
15000
81
80

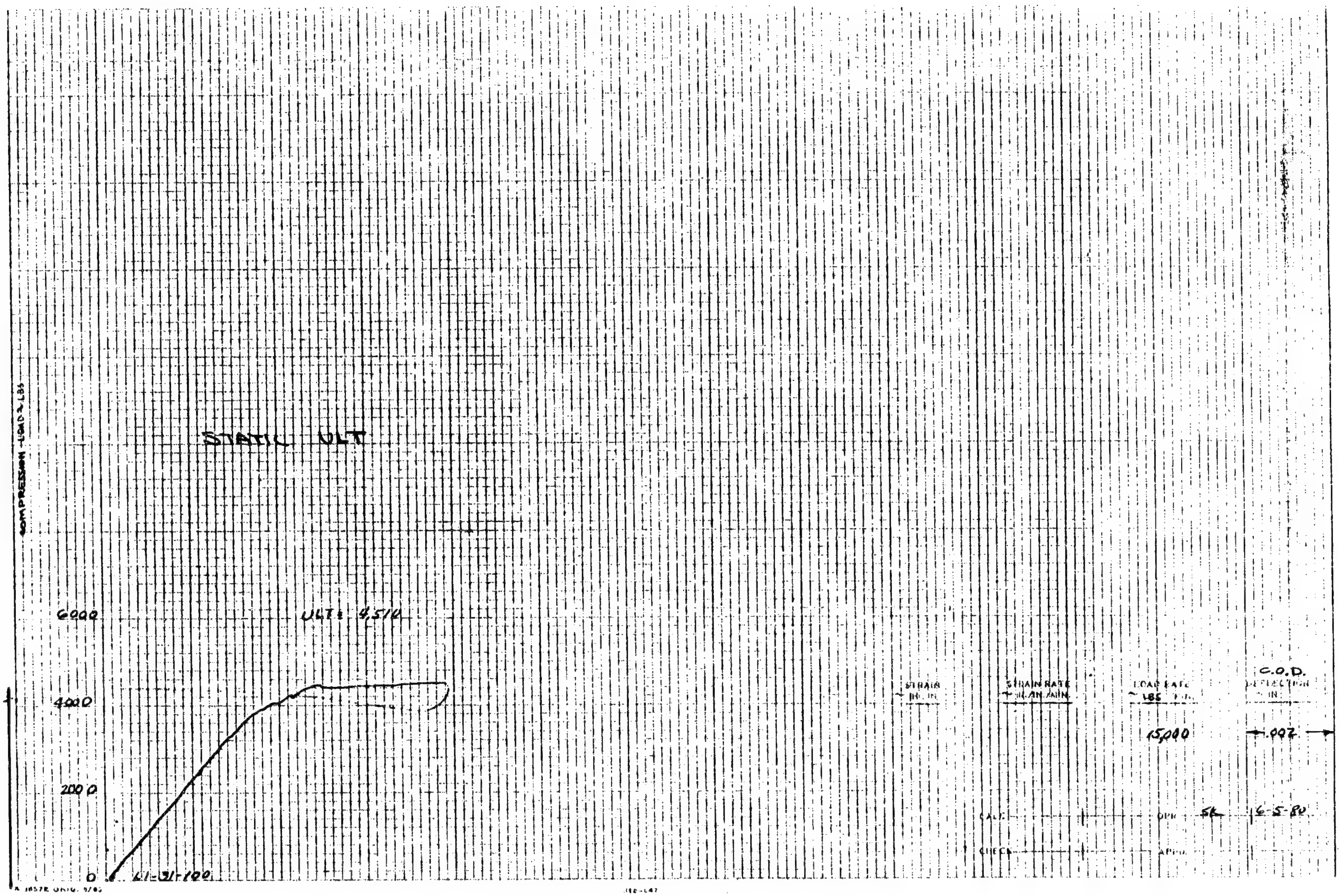

STATIC ULT
TENSION LOAD-LBS
20,000
15,000
10,000
5000
0
19,575
17,400
16,775
16,925
16,450
.016"
.008"
LJ-3
-75
-76
-82
-83
-84
STRAIN IN/IN
LOAD RATE LBS/MIN
15,000
COD DEFLECTION
.004
CALC
CHECK
CHK
APPD
5-7-80


17,775
14,575
STATIC ULT
TENSION LOAD ~ LBS
15,000
10,000
5000
0
L1-31
-90
-94
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE ~ LBS./MIN.
15,000
COD DEFLECTION ~ IN.
.004
CALC
CHECK
APPD
5-8-80


COD
.005
6-11-80
15,000
20,540
STATIC ULT
20000
16000
12000
8000



STATIC ULT
17,600
20000
10000
TENSION LOAD-LBS
COD
.005
15000
6-11-80


STATIC ULT
ULT: 4,510
COMPRESSION - LOAD ~ LBS
6000
4000
2000
0
L1-31-100
STRAIN ~ IN./IN.
STRAIN RATE ~ IN./IN./MIN.
LOAD RATE ~ LBS
15,000
C.O.D. DEFLECTION ~ IN.
.007
CALC.
CHECK
OPR. SK
APPD.
6-5-80

APPENDIX E

WEIGHT GAIN DATA

The tabulated weight gain data for each test specimen is included in this appendix as recorded during the course of making the measurements.

STATIC TEST SPECIMENS
UNTABBED LAMINATE

Specimen number	Week								
	0	1	2	3	4	5	6	7	8
L1-21-A	18.775	18.910							
L1-21-B	18.534	18.673	18.726						
L1-21-C	18.593	18.733	18.784	18.813	18.827				
L2-21-D	18.784	18.923	18.975	19.003	19.018	19.028	19.029	19.037	19.049
L2-21-A	19.812	19.956							
L2-21-B	19.555	19.700	19.758						
L2-21-C	19.864	20.011	20.069	20.102	20.120				
L2-21-D	19.379	19.526	19.585	19.615	19.632	19.643	19.646	19.653	19.665
L2-22-A	19.603	19.746							
L2-22-B	19.514	19.658	19.714						
L2-22-C	19.901	20.046	20.105	20.136	20.154				
L2-22-D	19.445	19.587	19.643	19.674	19.690	19.702	19.706	19.712	19.726
L2-23-A	20.339	20.494							
L2-23-B	20.345	20.497	20.550						
L2-23-C	20.407	20.561	20.621	20.657	20.677				
L2-23-D	19.951	20.106	20.166	20.199	20.218	20.228	20.234	20.241	20.254
L2-24-A	19.891	20.102							
L2-24-B	19.536	19.753	19.790						
L2-24-C	20.080	20.266	20.315	20.346	20.361				
L2-24-D	19.924	20.115	20.164	20.188	20.205	20.212	20.223	20.231	20.246
L3-21-A	19.667	19.790							
L3-21-B	19.479	19.598	19.664						
L3-21-C	19.778	19.902	19.971	20.014	20.038				
L3-21-D	19.531	19.659	19.727	19.780	19.792	19.804	19.810	19.818	19.831
L3-22-A	20.454	20.600							
L3-22-B	20.240	20.385	20.454						
L3-22-C	19.598	19.738	19.803	19.841	19.861				
L3-22-D	19.772	19.917	19.984	20.024	20.044	20.055	20.061	20.067	20.078

Note: Weight in grams

STATIC TEST SPECIMENS

Specimen number	Week 0	1	2	3	4	5	6	7	8
L1-21-1	173.847	175.574	176.210		176.670		176.880		176.960
L1-21-2	174.051	175.780	176.430		176.940		177.180		177.310
L1-21-3	174.951	176.661	177.320		177.860		178.050		178.190
L1-21-4	171.736	172.474	173.090		173.580		173.730		173.920
L1-21-5	173.914	175.643	176.200		176.770		176.940		177.020
L1-21-6	173.871	174.573	176.140		176.750		176.990		177.110
L1-21-7	173.074	174.782	175.370		175.960		176.210		176.340
L1-21-8	170.272	171.995	172.520		173.130		173.300		173.370
L1-21-9	174.040	175.750	176.280		176.940		177.060		177.160
L1-21-10	173.811	175.538	176.060		176.700		176.900		177.030
L1-21-11	174.543	176.260	176.790		177.470		177.690		177.860
L1-21-12	170.144	171.875	172.390		173.030		173.160		173.250
L1-21-13	173.340	175.040	175.570		176.250		176.360		176.430
L1-21-14	173.103	174.814	175.350		176.010		176.220		176.330
L1-21-15	173.546	175.264	175.790		176.460		176.640		176.790
L1-21-16	169.010	170.729	171.240		171.900		172.050		172.150
L1-21-17	173.112	174.840	175.370		176.030		176.150		176.290
L1-21-18	173.276	174.016	175.550		176.170		176.330		176.430
L1-21-19	174.185	175.910	176.440		177.090		177.310		177.500
L1-21-21	173.722	175.395	176.040		176.630		176.820		176.960
L1-21-22	171.840	173.490	174.150		174.720		174.920		175.090
L1-21-23	172.085	173.747	174.410		175.000		175.090		175.370
L1-21-24	167.702	169.341	170.020		170.570		170.630		170.870
L1-21-25	171.175	172.801	173.480		174.100		174.090		174.320
L1-21-26	170.290	171.931	172.600		173.170		173.220		173.510
L1-21-27	171.101	172.750	173.410		173.960		174.070		174.360
L1-21-28	166.723	168.359	169.020		169.530		169.720		169.840
L1-21-29	170.807	172.427	173.080		173.610		173.720		173.940

Note: Weight in grams

STATIC TEST SPECIMENS

Specimen number	Week								
	0	1	2	3	4	5	6	7	8
L1-21-30	170.408	172.130	172.780		173.320		173.460		173.750
L1-21-31	172.104	173.758	174.420		174.950		175.060		175.330
L1-21-32	167.594	169.230	169.920		170.410		170.490		170.740
L1-21-33	170.395	172.052	172.700		173.240		173.330		173.600
L1-21-34	170.334	171.988	172.630		173.170		173.300		173.600
L1-21-35	171.551	173.195	173.860		174.410		174.510		174.800
L1-21-36	166.663	168.338	168.990		169.510		169.610		169.860
L1-21-37	171.380	173.040	173.700		174.220		174.340		174.630
L1-21-38	171.473	173.136	173.810		174.310		174.450		174.730
L1-21-39	173.910	175.597	176.260		176.810		177.000		177.140
L1-21-41	171.163	172.864	173.530		174.000		171.150		174.240
L1-21-42	174.212	174.900	176.580		177.080		177.340		178.490
L1-21-43	174.086	175.770	176.460		176.980		177.190		178.330
L1-21-44	172.606	174.292	174.960		175.450		175.560		175.660
L1-21-45	171.720	173.422	174.080		174.570		174.690		174.810
L1-21-46	174.400	176.084	176.760		177.240		177.540		177.720
L1-21-47	174.293	175.972	176.540		177.180		177.400		177.630
L1-21-48	172.897	174.601	175.170		175.760		175.900		176.000
L1-21-49	173.005	174.702	175.230		175.850		176.010		176.130
L1-21-50	174.522	176.214	176.760		177.430		177.650		177.860
L1-21-51	174.414	176.100	176.660		177.320		177.520		177.700
L1-21-52	171.964	173.666	174.200		174.830		174.950		175.050
L1-21-53	173.264	174.970	175.510		176.170		176.260		176.360
L1-21-54	175.117	176.820	177.370		178.040		178.260		178.420
L1-21-55	174.713	176.410	176.960		177.630		177.820		177.990
L1-21-56	171.992	173.711	174.250		174.900		175.010		175.110
L1-21-57	173.445	174.150	175.700		176.340		176.540		176.690
L1-21-58	174.490	176.224	176.890		177.400		177.540		177.650

Note: Weight in grams

STATIC TEST SPECIMENS

Specimen number	Week 0	1	2	3	4	5	6	7	8
L1-21-59	173.679	175.375	176.030		176.560		176.710		176.800
L1-21-61	175.441	177.028	177.690		178.280		178.590		178.790
L1-21-62	174.730	176.322	177.000		177.580		177.850		178.060
L1-21-63	176.150	177.768	178.430		179.650		179.310		179.520
L1-21-64	171.810	173.423	174.060		174.670		174.940		175.140
L1-21-65	175.865	177.479	178.120		178.740		179.010		179.240
L1-21-66	175.344	176.938	177.600		178.190		178.470		178.690
L1-21-67	175.778	177.383	178.040		178.600		178.940		179.110
L2-21-1	171.558	173.353	173.854		174.429		174.682		174.898
L2-21-2	174.237	175.931	176.480		177.105		177.391		177.625
L2-21-3	174.077	175.777	176.326		176.945		177.246		177.503
L2-21-4	175.950	177.730	178.241		178.802		179.050		179.246
L2-21-5	171.236	172.940	173.522		174.079		174.352		174.556
L2-21-6	173.606	175.304	175.854		176.466		176.763		176.940
L2-21-7	173.932	175.640	176.196		176.809		177.109		177.330
L2-21-8	175.592	177.316	177.883		178.460		178.733		178.926
L2-21-9	171.140	172.860	173.419		173.983		174.250		174.436
L2-21-10	173.596	175.286	175.842		176.447		176.735		176.934
L2-21-11	173.945	175.636	176.191		176.799		177.102		177.309
L2-21-12	174.803	176.500	177.060		177.620		177.884		178.058
L2-21-21	169.808	171.523	172.094		172.650		172.898		173.041
L2-21-22	172.092	173.772	174.320		174.910		174.208		174.392
L2-21-23	172.161	173.846	174.398		174.990		175.266		175.437
L2-21-24	173.607	175.290	175.861		176.446		176.707		176.890
L2-21-25	170.197	171.900	172.465		173.030		173.275		173.442
L2-21-26	172.364	174.019	174.611		175.198		175.475		175.662
L2-21-27	173.353	175.028	175.618		176.209		176.495		176.668

Note: Weight in grams

STATIC TEST SPECIMENS

Specimen number	Week								
	0	1	2	3	4	5	6	7	8
L2-21-28	174.323	176.033	176.596		177.166		177.429		177.600
L2-21-29	169.900	171.645	172.202		172.719		172.956		173.119
L2-21-30	172.937	174.606	175.209		175.792		176.061		176.224
L2-21-31	173.056	174.720	175.321		174.920		176.191		176.378
L2-21-32	173.370	175.153	175.630		176.170		176.301		176.545
L2-21-41	173.860	175.623	176.167		176.662		176.818		176.945
L2-21-42	171.730	173.439	174.041		174.580		174.790		174.967
L2-21-43	171.856	173.544	174.135		174.675		174.884		175.010
L2-21-44	169.760	171.470	172.045		172.541		172.693		172.794
L2-21-45	173.506	175.281	175.825		176.273		176.413		176.489
L2-21-46	171.467	173.162	173.749		174.292		174.513		174.670
L2-21-47	172.090	173.785	174.365		174.904		175.110		175.273
L2-21-48	169.990	171.776	172.298		172.740		172.910		172.978
L2-21-49	173.435	175.190	175.727		176.251		176.412		176.538
L2-21-50	170.704	172.411	172.994		173.530		173.762		173.964
L2-21-51	170.434	172.144	172.725		173.262		173.467		173.644
L2-21-52	169.510	171.251	171.788		172.262		172.382		172.508
L2-21-61	175.871	177.671	178.223		178.730		178.874		179.030
L2-21-62	173.536	175.283	175.877		176.443		176.658		176.845
L2-21-63	173.695	175.430	176.025		176.587		176.791		176.969
L2-21-64	173.150	174.963	175.504		176.007		176.144		176.269
L2-22-1	172.917	174.538	175.096		175.725		176.014		176.268
L2-22-2	173.630	175.227	175.806		176.452		176.748		177.010
L2-22-3	174.840	176.425	177.008		177.659		177.966		178.238
L2-22-4	169.060	170.691	171.244		171.864		172.148		172.396
L2-23-1	174.300	175.989	176.552		177.205		177.508		177.751

Note: Weight in grams

STATIC TEST SPECIMENS

Specimen number	Week								
	0	1	2	3	4	5	6	7	8
L2-23-2	175.480	177.117	177.714		178.375		178.687		178.960
L2-23-3	174.650	176.325	176.924		177.588		177.898		178.187
L2-23-4	169.060	176.034	176.610		177.260		177.565		177.747
L2-24-1	173.125	175.334	175.794		176.281		176.474		176.756
L2-24-2	173.589	175.540	176.164		176.640		176.856		177.100
L2-24-3	175.576				178.665		178.890		179.122
L2-24-4	170.206	172.320	172.812		173.306		173.511		173.750
L3-21-1	176.234	177.804	178.454		179.142		179.450		179.677
L3-21-2	175.989	177.513	178.177		178.890		179.225		179.484
L3-21-3	175.653	177.192	177.858		178.563		178.906		179.166
L3-21-4	170.752	172.385	173.002		173.661		173.978		174.221
L3-21-5	176.117	177.700	178.332		179.032		179.369		179.735
L3-21-6	176.528	178.056	178.720		179.422		179.760		180.030
L3-21-7	174.898	176.424	177.091		177.778		178.118		178.373
L3-21-8	170.460	172.090	172.715		173.360		173.682		173.921
L3-21-9	176.426	178.003	178.647		179.340		179.676		179.427
L3-21-10	176.818	178.348	179.006		179.709		180.042		180.286
L3-21-11	174.563	176.090	176.737		177.423		177.353		177.984
L3-21-12	173.247	173.790	174.426		175.068		175.386		175.628
L3-21-21	169.552	171.144	171.780		172.410		172.710		172.949
L3-21-22	175.720	177.227	177.877		178.570		178.911		179.169
L3-21-23	177.082	178.605	179.227		179.983		180.330		180.596
L3-21-24	175.468	177.012	177.643		178.335		178.671		178.922
L3-21-25	170.044	171.636	172.260		172.896		173.210		173.462
L3-21-26	176.266	177.776	178.418		179.115		179.470		179.725
L3-21-27	175.755	177.258	177.895		178.596		178.950		179.207

Note: Weight in grams

STATIC TEST SPECIMENS

Specimen number	Week								
	0	1	2	3	4	5	6	7	8
L3-21-28	174.915	176.470	177.085		177.774		178.130		178.355
L3-21-29	169.396	170.996	171.634		172.243		172.570		172.812
L3-21-30	177.720	179.216	179.878		180.597		180.961		181.243
L3-21-31	175.926	177.416	178.063		178.767		179.103		179.360
L3-21-32	175.524	177.066	177.699		178.569		178.685		178.894
L3-21-41	175.598	177.148	177.792		178.474		178.801		179.042
L3-21-42	175.687	177.203	177.853		178.560		178.895		179.160
L3-21-43	175.166	176.695	177.342		178.047		178.378		178.642
L3-21-44	170.514	172.121	172.752		173.412		173.707		173.951
L3-21-45	175.096	176.650	177.267		177.976		178.303		178.525
L3-21-46	175.939	177.452	178.103		178.815		179.159		179.416
L3-21-47	173.562	175.074	175.718		176.410		176.730		176.984
L3-21-48	169.655	171.232	171.966		172.534		172.841		173.070
L3-21-49	174.324	175.880	176.522		177.215		177.539		177.779
L3-21-50	175.518	177.032	177.693		178.395		178.729		178.978
L3-21-51	173.218	174.729	175.380		176.056		176.329		176.618
L3-21-52	171.631	173.168	173.800		174.433		174.760		176.989
L3-21-61	169.868	171.475	172.121		172.734		173.034		173.250
L3-21-62	175.812	177.333	177.988		178.685		179.019		179.276
L3-21-63	175.635	177.148	177.810		178.506		178.846		179.097
L3-21-64	175.660	177.208	177.857		178.515		178.819		179.043
L3-22-1	176.420	178.010	178.656		179.400		179.575		179.779
L3-22-2	173.730	175.325	175.982		176.700		176.919		177.128
L3-22-3	176.400	177.996	178.663		179.390		179.609		179.812
L3-22-4	172.144	173.769	174.420		175.140		175.319		175.537
L3-22-5	176.093	177.724	178.367		179.080		179.315		179.512
L3-22-6	174.692	176.303	176.948		177.680		177.890		178.092

Note: Weight in grams

STATIC TEST SPECIMENS

Specimen number	Week								
	0	1	2	3	4	5	6	7	8
L3-22-7	175.535	177.133	177.785		178.510		178.740		178.942
L3-22-8	173.576	175.197	175.832		176.560		176.753		176.955
L3-22-9	172.258	173.812	174.452		175.160		175.367		175.558
L3-22-21	174.449	176.032	176.655		177.250		177.599		177.815
L3-22-22		174.458	175.103		175.820		176.051		176.265
L3-22-23	176.505	178.063	178.725		179.470		179.698		179.918
L3-22-24	171.812	173.449	174.084		174.770		175.006		175.215

Note: Weight in grams

CYCLIC TEST SPECIMENS
UNTABBED LAMINATE

SPECIMEN NUMBER	INITIAL WEIGHT (g)	1 WEEK WEIGHT (g)	2 WEEK WEIGHT (g)	3 WEEK WEIGHT (g)	4 WEEK WEIGHT (g)	6 WEEK WEIGHT (g)	8 WEEK WEIGHT (g)	POST-TEST WEIGHT 1 (g)	Δt 2 (IN)
L1-1	16.3018	16.4100	--	--	--	--	--	--	.0009
-2	16.4907	16.6020	--	--	--	--	--	--	.0010
-3	17.0016	17.1191	17.1725	--	--	--	--	--	.0010
-4	17.5768	17.9990	18.0527	18.0813	18.1031	18.1331	--	--	.0015
L1-5	17.4347	17.5539	17.6078	17.6379	17.6597	17.6885	17.7024	--	.0010
L3-1	16.3478	16.4490	--	--	--	--	--	--	.0006
-2	17.4071	17.5201	--	--	--	--	--	--	.0002
-3	16.6028	16.7170	16.7752	--	--	--	--	--	.0010
-4	17.7412	17.8561	17.9179	17.9532	17.9774		18.0018	--	.0012
L3-5	17.3719	17.4840	17.5456	17.5769	17.5984	17.6246	17.6366	--	.0010

CYCLIC TEST SPECIMENS

SPECIMEN NUMBER	INITIAL WEIGHT (g)	1 WEEK WEIGHT (g)	2 WEEK WEIGHT (g)	3 WEEK WEIGHT (g)	4 WEEK WEIGHT (g)	6 WEEK WEIGHT (g)	8 WEEK WEIGHT (g)	POST-TEST WEIGHT [1] (g)	ΔT [2] (IN)
L1-31-25	173.9663	175.3480	176.0412	176.4707	176.8334	177.2609	177.5203	--	.002
-26	177.1086	178.5035	179.2368	179.6499	180.0209	180.4889	180.7839	--	.002
-27	174.2561	175.6922	176.3800	176.8109	177.1666	177.6339	177.9021	--	.002
-28	174.5697	176.0275	176.7257	177.1446	177.4900	177.9597	178.2452	179.1433	.002
-29	172.8269	174.2592	174.9309	175.3636	175.7104	176.1870	176.4573	177.2737	.002
-30	171.9496	173.3513	174.0765	174.5104	174.8759	175.3402	175.5927	--	.003
-31	176.3698	177.7885	178.4801	178.9156	179.2746	179.7473	180.0364		.002
-32	175.6493	177.0730	177.8005	178.2152	178.5825	179.0383	179.2949		.002
-33	176.0354	177.4776	178.1696	178.5953	178.9558	179.3808	179.6853		.002
-34	177.6780	178.9027	179.5849	180.0146	180.3807	180.8543	181.1329		.003
-45	171.4104	172.8120	173.5165	173.9429	174.2862	174.7493	175.0150		.003
-46	176.1933	177.6570	178.3735	178.7823	179.1286	179.5684	179.7603		.001
-47	176.6724	178.1500	178.8089	179.2406	179.5858	179.9806	180.2225	--	.002
-48	178.9384	180.4486	181.1853	181.6624	181.9782	182.3744	182.6039	183.3423	.002
-49	173.5899	175.1135	175.8123	176.2223	176.5362	176.9220	177.1609	177.7933	.002
-50	174.2360	176.2497	176.9363	177.3162	177.6453	178.0577	178.2869	--	.001
-51	176.6392	178.1130	178.7763	179.1854	179.5185	179.9173	180.1901	--	.002
-52	174.8657	176.3635	177.0401	177.4659	177.8006	178.2310	178.4657	--	.002
-53	173.9534	175.4082	176.0905	176.4982	176.8372	177.2294	177.4857	176.4448	.003
-60	174.3782	175.7920	176.4836	176.9257	177.2537	177.7359	178.0305	--	.001
-64	178.0692	179.4672	180.1722	180.6148	180.9824	181.4509	181.7278	--	.002
-65	176.4795	177.9055	178.6109	179.0344	170.4371	179.8518	180.1290	--	.001
-66	174.3568	175.8600	176.5307	176.9272	177.2639	177.6802	177.9017	--	.001
-67	173.6507	175.1908	175.8258	176.2282	176.5541	177.0059	177.2076	--	.002
-68	177.2446	178.8111	179.4462	179.8820	180.2154	180.6047	180.8522	181.2025	.002
-69	176.0571	177.5316	178.1688	178.6104	178.9662	179.3550	179.5969	--	.001
-70	176.8531	178.3705	179.0117	179.4432	179.8221	180.2674	180.5149	--	.002
-71	175.9640	177.4100	178.0537	178.4904	178.8093	179.2240	179.4726	--	.002
-72	173.4033	174.9080	175.5725	175.9807	176.3233	176.7108	176.9617	177.3314	.002
-73	174.0064	175.4320	176.1334	176.5428	176.8875	177.3012	177.5445	176.6219	.002
-90	179.5883	180.9537	181.6707	182.1103	182.5006	183.0223	183.3135	--	.002
-91	180.5374	181.8734	182.5769	183.0453	183.4375	183.8925	184.1639	184.7209	.002
-92	173.9853	175.3399	176.0307	176.4868	176.8325	177.3080	177.5642	177.3832	.002
-93	180.5600	181.9410	182.6336	183.1226	183.5159	183.9983	184.2851	--	.002
-94	179.0833	180.4661	181.2043	181.6316	182.0098	182.4721	182.7830	--	.002
-95	176.5762	177.9863	178.6787	179.1128	179.4798	179.9512	180.2322	--	.002
-96	175.4752	176.8998	177.6163	178.0513	178.4159	178.9008	179.1929	--	.002
-97	171.3532	172.7230	173.3901	173.8081	174.1609	174.6187	174.8810	175.3081	.001
-98	176.3297	177.6925	178.3896	178.8158	179.2018	179.6626	179.9459	--	.001
-99	178.1413	179.5495	180.2229	180.6939	181.0650	181.5511	181.8435	179.3209	.002 [3]
L1-31-100	174.5703	175.9191	176.5896	177.0201	177.3835	177.8528	178.1331	178.0334	.002

[1] Upon completion of cyclic loading, specimens were wrapped in wet cloth and stored in plastic bags. Specimens were weighed approx. 20-30 days post-test.

[2] Difference in thickness measurements made before and after eight-week soak.

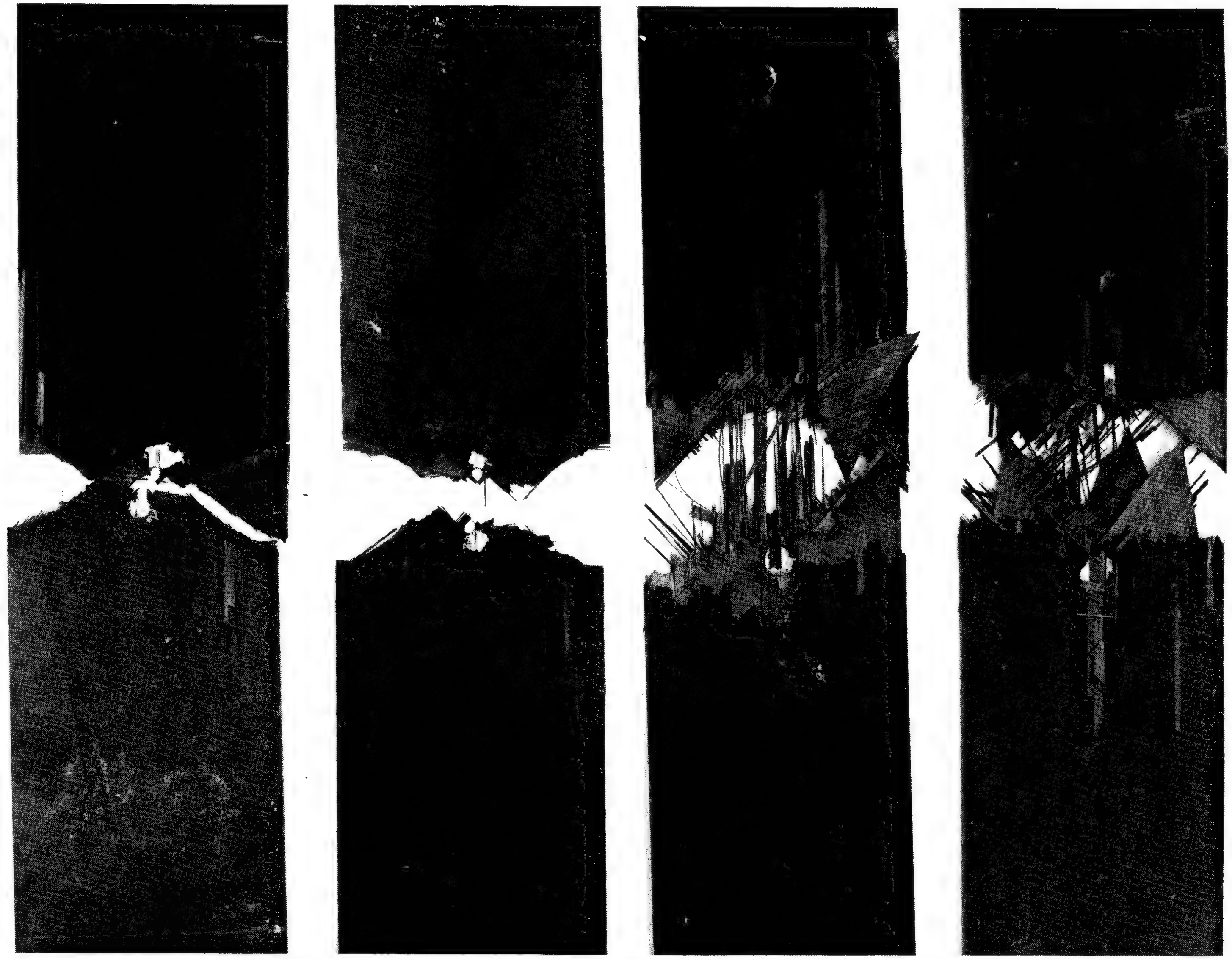
[3] Post-test weight measured immediately upon removal from test machine.

TABLE III
MOISTURE CONDITIONING DATA

APPENDIX F

PHOTOGRAPHS OF FAILED TEST SPECIMENS

This appendix contains photographs of typical test specimens after completion of the testing. The specimens are identified by specimen number, defect code and testing history.



L1-21-5 ROOM | L1-21-6 ROOM | L1-21-7 422K | L1-21-8 422K

STATIC TEST SPECIMENS (WET)
1/8 FP HOLE

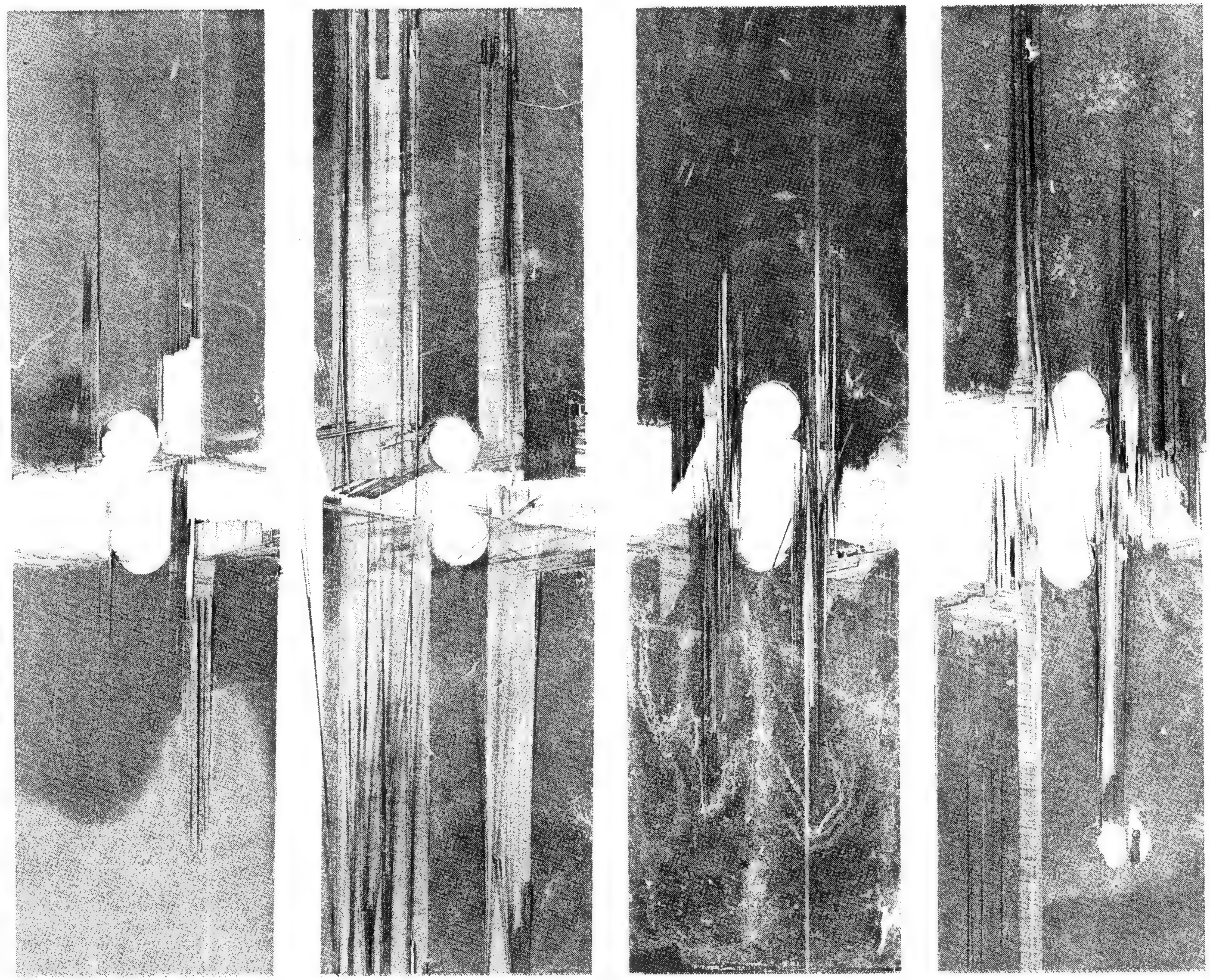
L1-21-41
ROOM

L1-21-42
ROOM

L1-21-43
422K

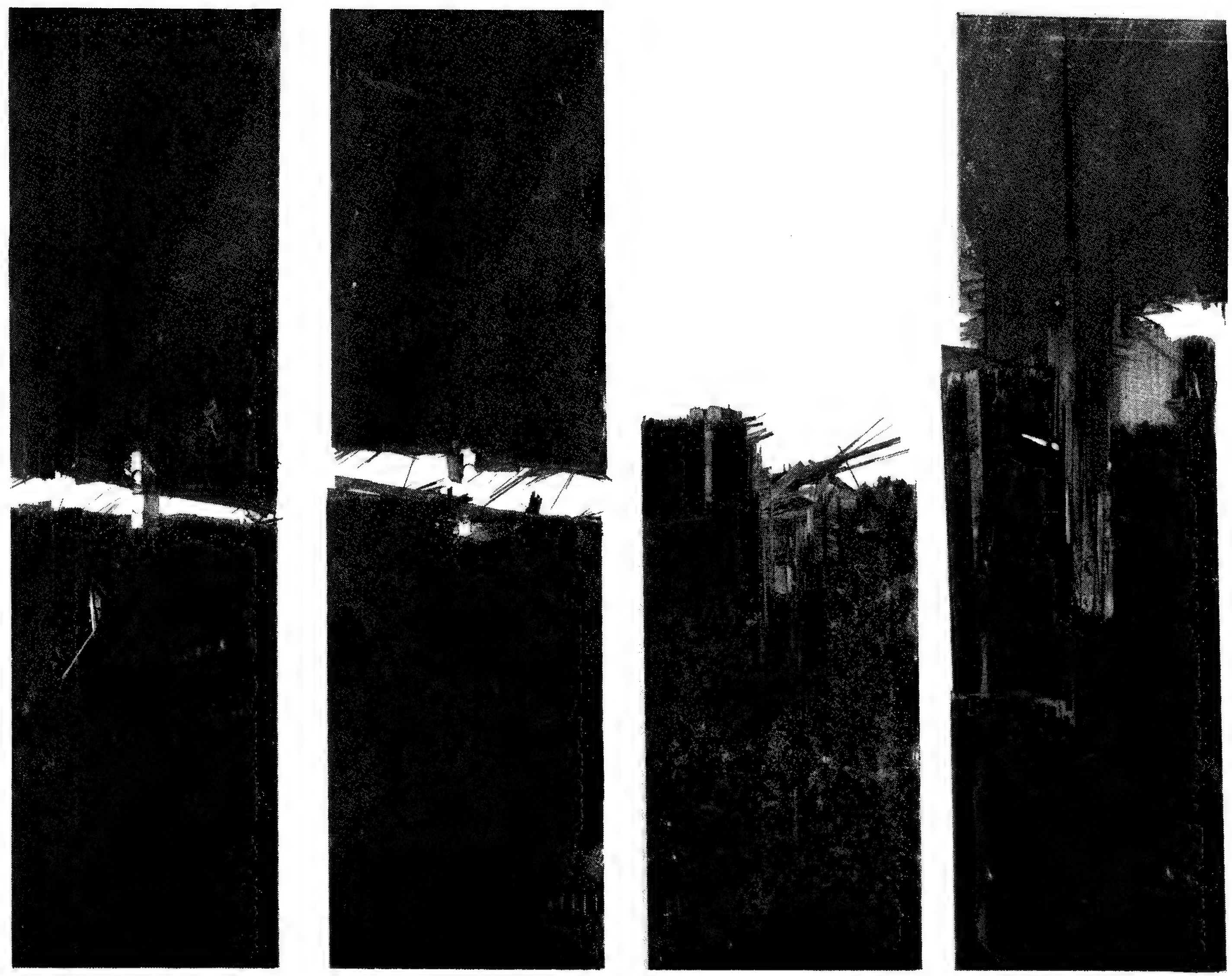
L1-21-44
422K

STATIC TEST SPECIMENS (WET)
1/8 HP HOLE



L2-21-21 ROOM | L2-21-22 ROOM | L2-21-23 422K | L2-21-24 422K

STATIC TEST SPECIMENS (WET)
5/8 FP HOLE



L2-21-5
ROOM

L2-21-6
ROOM

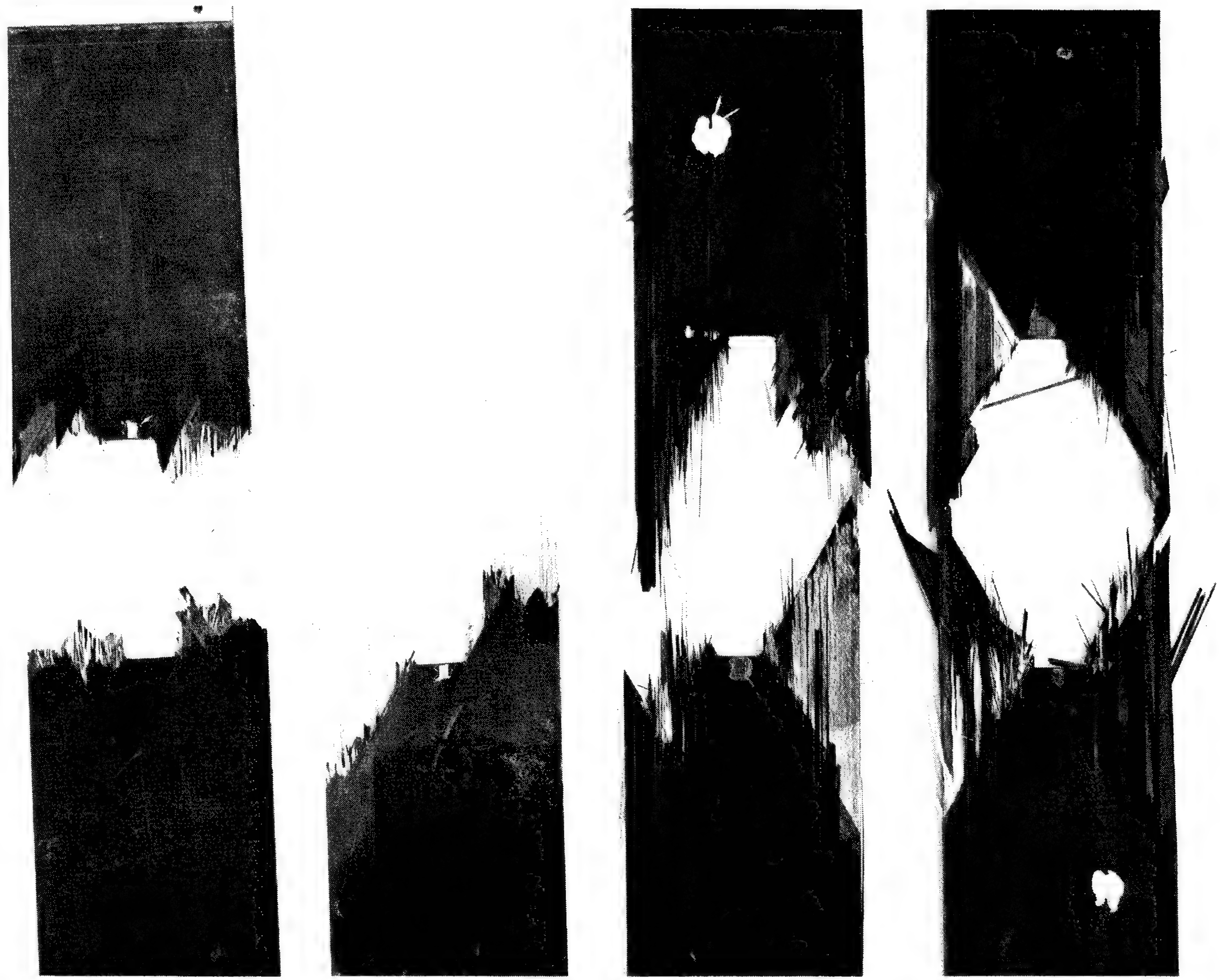
L2-21-7
422K

L2-21-8
422K

STATIC TEST SPECIMENS (WET)
1/8 FP HOLE

L3-21-21 ROOM | L3-21-22 ROOM | L3-21-23 422K | L3-21-24 422K

STATIC TEST SPECIMENS (WET)
1/8 HP SLIT



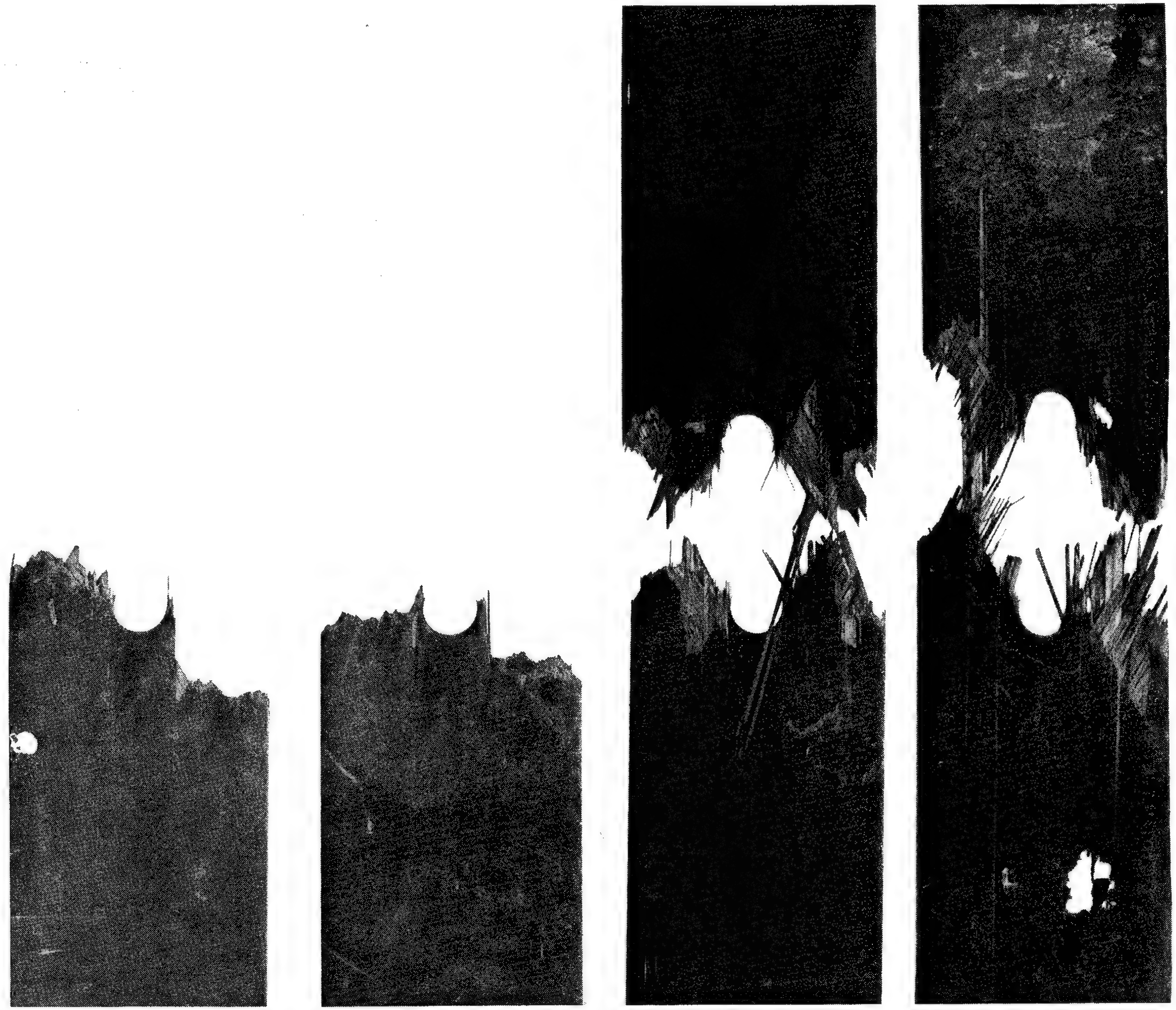
L3-21-9
ROOM

L3-21-10
ROOM

L3-21-11
422K

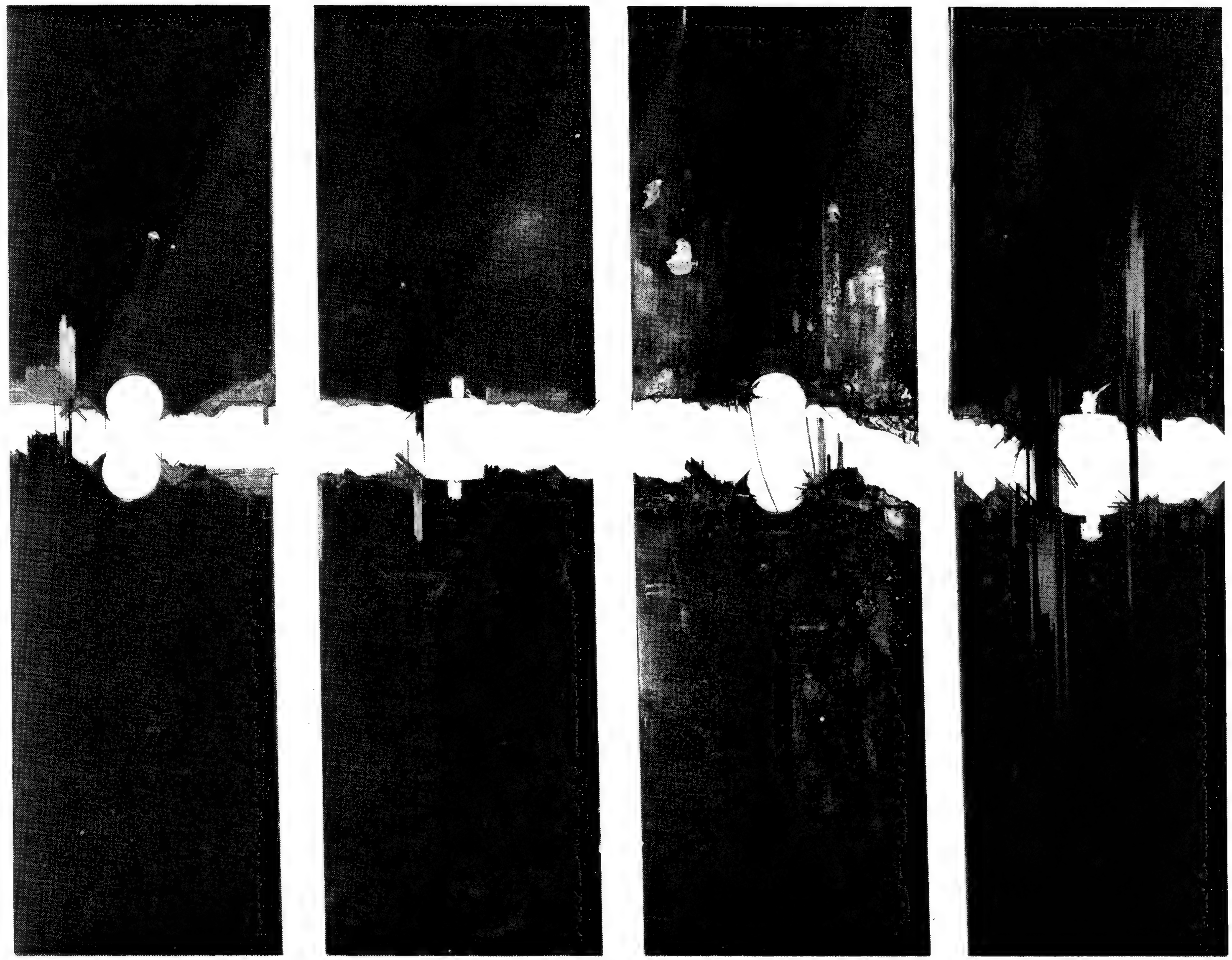
L3-21-12
422K

STATIC TEST SPECIMENS (WET)
5/8 FP SLIT



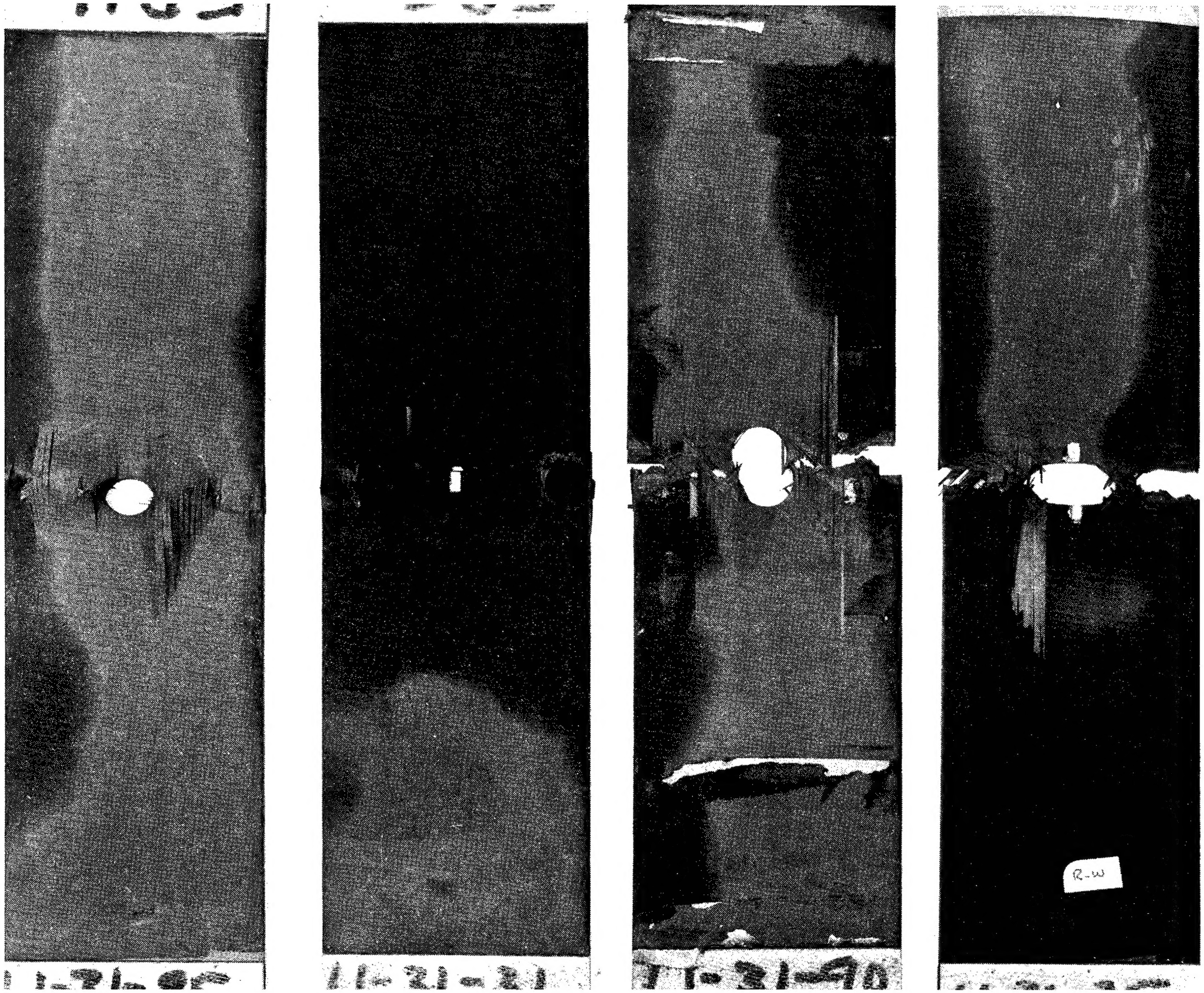
L3-22-21 ROOM | L3-22-22 ROOM | L3-22-23 422K | L3-22-24 422K

STATIC TEST SPECIMENS (WET)
5/8 FP HOLE



L1-31-80 R = 0.05 | L1-31-35 R = 0.05 | L1-31-77 R = -1.00 | L1-31-41 R = -1.00

CYCLIC TEST SPECIMENS (DRY)
ROOM TEMPERATURE



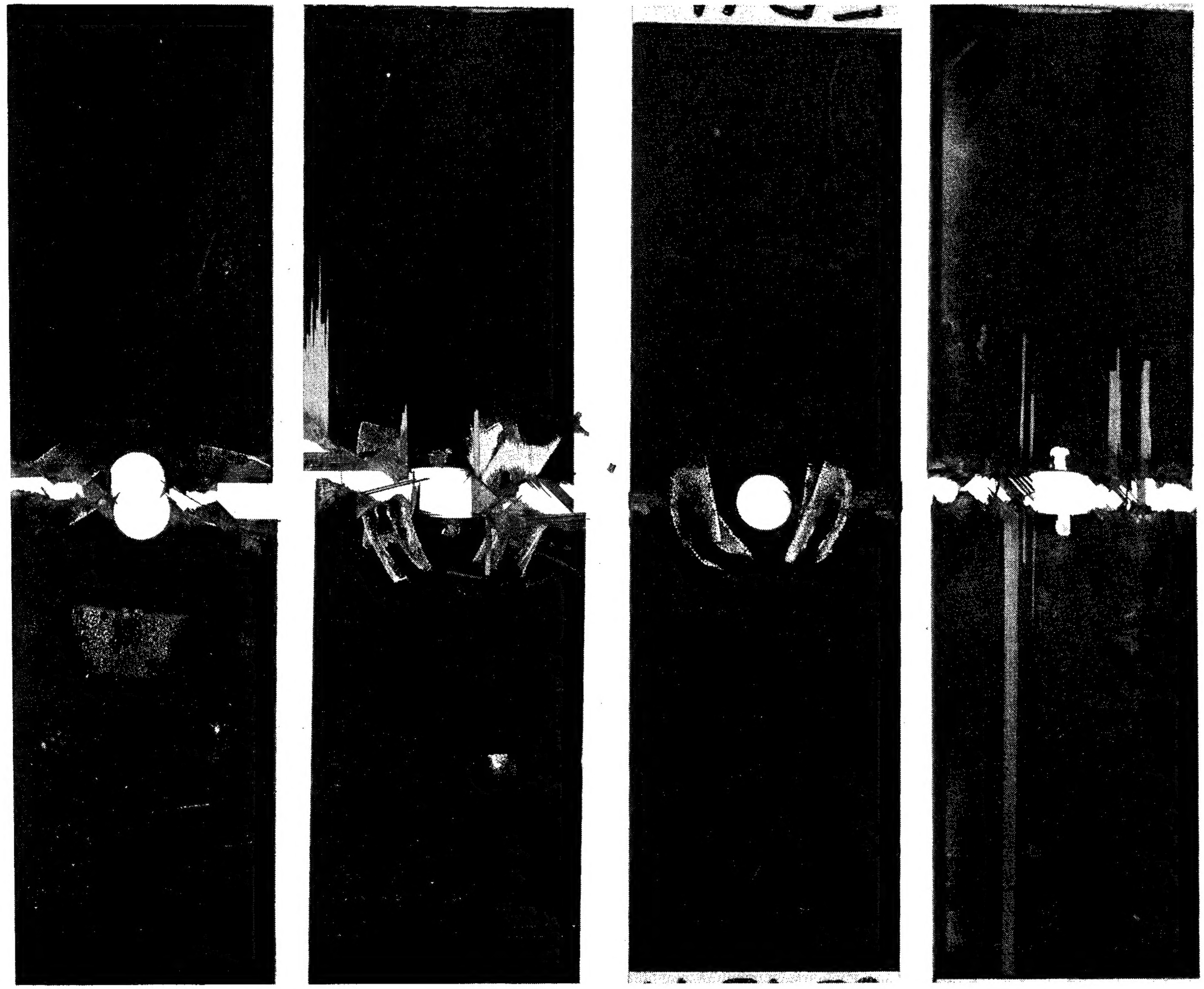
L1-31-95
R = -1.00

L1-31-31
R = -1.00

L1-31-90
R = 0.05

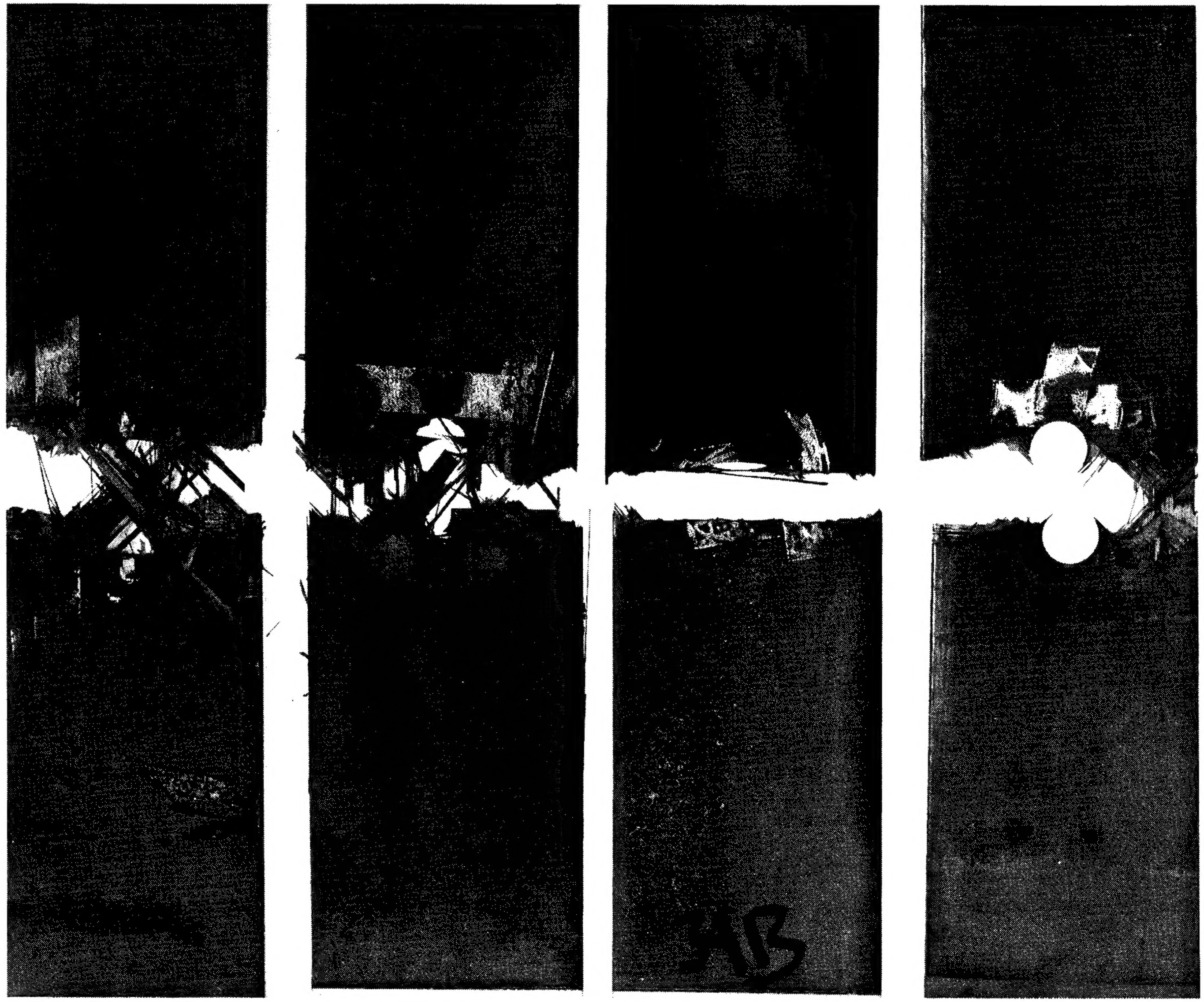
L1-31-25
R = 0.05

CYCLIC TEST SPECIMENS (WET)
ROOM TEMPERATURE



L1-31-82 R = 0.05 | L1-31-61 R = 0.05 | L1-31-89 R = -1.00 | L1-31-59 R = -1.00

CYCLIC TEST SPECIMENS (DRY)
422K ($300^{o}F$)



L1-31-49
R = 0.05

L1-31-93
R = 0.05

L1-31-34
R = -1.00

L1-31-73
R = -1.00

CYCLIC TEST SPECIMENS (WET)
422K ($300^{\circ}F$)

1. Report No.
NASA CR-165213

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
ENVIRONMENTAL EFFECTS ON DEFECT GROWTH IN COMPOSITE MATERIALS

5. Report Date
January 1981

6. Performing Organization Code

7. Author(s)
T. R. Porter

8. Performing Organization Report No.
D180-26968-1

9. Performing Organization Name and Address
Boeing Military Airplane Company
P.O. Box 3707
Seattle, Washington 98124

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16. Abstract

This report presents the results of a program investigating the effects of moisture and temperature on the fatigue and fracture response of composite laminates containing defects. The structural laminates investigated were: (1) a typical angle ply laminate, (2) a polar and hoop wound pressure vessel laminate, and (3) a typical turbine-engine fan blade laminate. Defects investigated were: (1) full- and half-penetration circular holes, (2) full- and half-penetration slits, (3) countersunk holes, and (4) impact delaminations. Results are presented showing the effects of moisture on the fracture and fatigue strength at room temperature and 422K (300°F). Static test results are presented that show the effects of defect size and type on the fracture strength under moisture and thermal environments. The cyclic test results compare the fatigue lives and residual tensile strength under tension only and under tension-compression loading. Damage growth data from ultrasonic inspections, visual examinations, and crack operating displacement records are presented.

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T300/9945901 - F.berite 934

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